METALLURGIA

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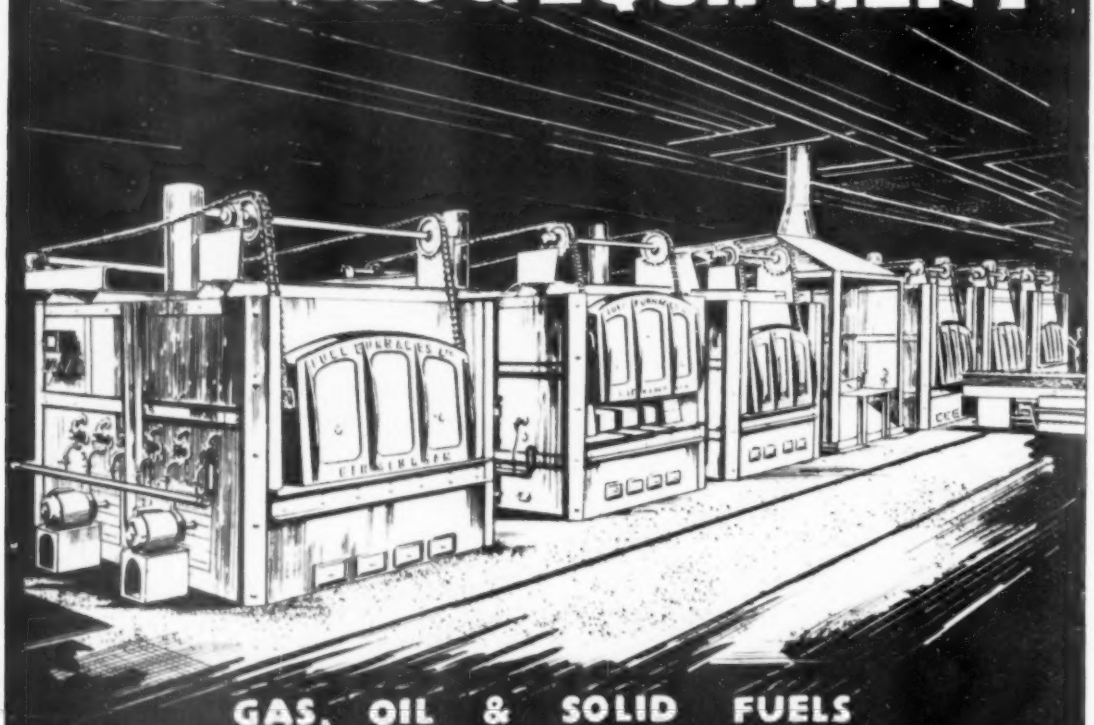

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INCORPORATING THE METALLURGICAL ENGINEER

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CONTRIBUTIONS

Readers are invited to submit articles for publication in the editorial pages: photographs and/or drawings suitable for reproduction are especially welcome. Contributions are paid for at the usual rates. We accept no responsibility in connection with submitted manuscript. All editorial communications should be addressed to The Editor, "Metallurgia," 31, King Street West, Manchester, 3.

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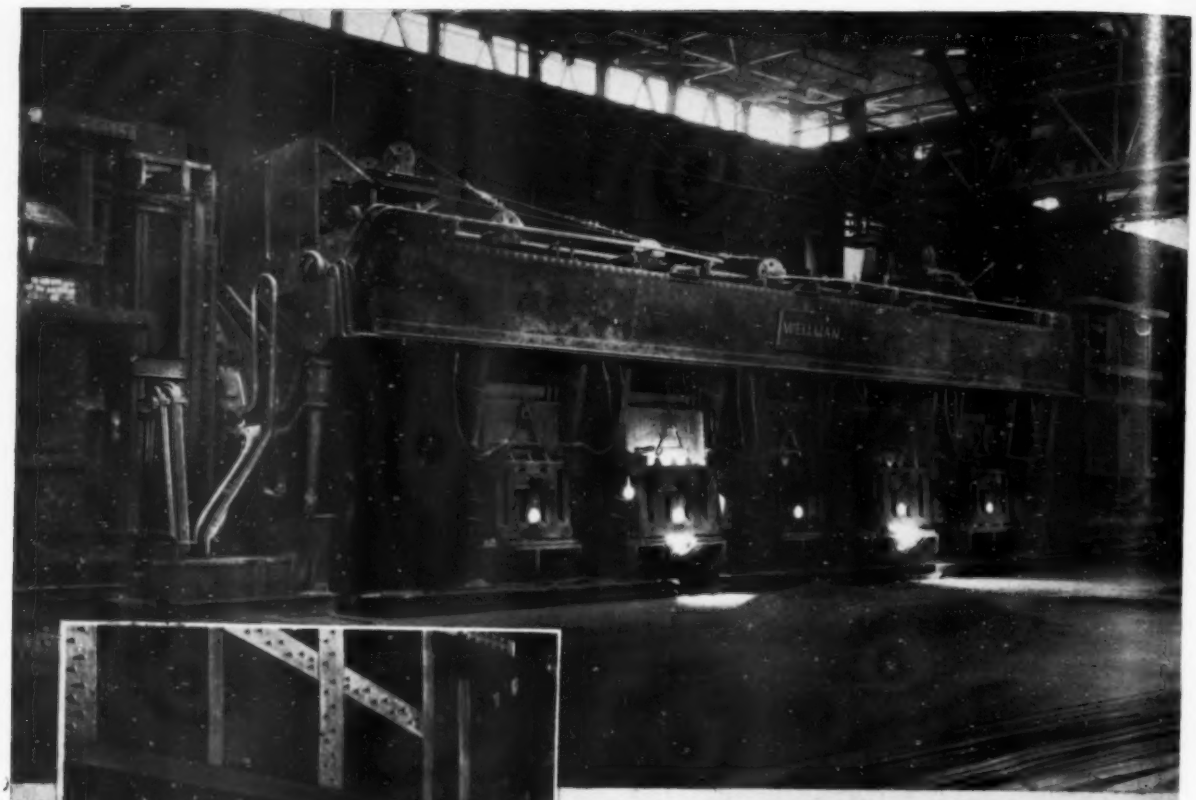

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THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

AUGUST, 1955 Vol. LII. No. 310

Human Problems in Industry

IT is just over twelve months since fifty industrialists and trade unionists were invited, in their individual capacities, to a meeting to advise H.R.H. The Duke of Edinburgh about a suggestion to hold a study conference dealing with the human problems of industrial communities in the Commonwealth and Empire. The matter had been raised with him in his capacity as Patron of the Industrial Welfare Society, on his return from a long visit with the Queen to many of the countries concerned, and from what he had seen he felt that the idea had much to commend it. His Royal Highness was anxious to find out whether such a conference was thought to be practicable, and to ensure that if it went forward it would do so on lines worthy of such an imaginative conception. There was strong support for the general idea, and several committees were appointed to consider the main aspects of the proposal. As a result of their recommendations, a second meeting in December decided to form itself into a conference council, and H.R.H. The Duke of Edinburgh graciously consented to be President of a Conference to be held in Oxford in July, 1956, under the title of "H.R.H. The Duke of Edinburgh's Study Conference on the Human Problems of Industrial Communities Within the Commonwealth and Empire."

In conducting a practical study of the human aspects of industrialisation, and in particular those factors which make for satisfaction, efficiency and understanding, both within industrial organisations and in the everyday relations between industry and the community around it, the conference will not deal with matters which come within the normal scope of industrial negotiation. It has become quite clear to those who have studied the matter that no complete answer to the problem of improving human relationships in industry can be found within the factory precincts. The motives for work, the satisfaction of those engaged in it, and the acceptance of discipline and leadership are greatly influenced by social and political traditions, by the pattern of family and community life, and by the values, fears and aspirations of the individual and social groups. Again, studies of social development have often emphasized the effects of industrialisation on the traditional life of the community, effects which have been striking and far reaching. It is obvious, therefore, that whether man works to live, or lives to work, there is interaction at all points between industry and social life.

The industrial revolution wrought sweeping changes which induced violent reaction, largely because the developments inherent in the rapid technical and industrial progress of the times were made with little or no regard for the social consequences. In the intervening years industrial progress has been continuous, if, perhaps, less violent, but the gradually changing pattern of industrial life has, nevertheless, had its repercussions on the habits of the community. This is as true today as at any time, and if the present is, perhaps a bloodless revolution, it is nevertheless real and deep-seated. The word "automation" has been much in the news of late, and although it is merely an extension of ideas which have been applied on a relatively smaller scale for a long time, it is bound to have important repercussions on community life.

There are today in the Commonwealth and Empire communities at all stages of industrial development. Some, indeed are feeling for the first time the impact of new techniques and social groupings on older ways of life and work. In such cases, emphasised perhaps by speed of change, racial tensions, or population growth, the difficulties may seem more obvious—as did those of our own industrial revolution—but countries such as ours, older in industrial history, with much to contribute from experience, have also their problems, and particularly complex some of them are. Furthermore, the annihilation of distance by improved transport and communications may result, in the less industrially developed areas, in more spectacular progress than any yet seen.

Although the conference, with its membership drawn solely from industry and with the limited time available, cannot tackle in their entirety such questions as how can we reconcile the benefits of industrial development with personal needs, and how can the life of a community assimilate the changes which accompany a technical and economic revolution, it can examine in a practical way the factors within industry itself and its immediate environment which are most likely to affect the response to economic and social change.

The conference membership will be composed of men and women of the Commonwealth and Empire, broadly within the age group of twenty-five to forty-five, who are engaged in managerial, technical or operative work in industry, who hold—or in the foreseeable future will hold—positions of responsibility, and who have a proven interest in the life of their community.

This conference is essentially an experiment in common effort within the Commonwealth and Empire. Many of the problems it will study have indeed been considered before; but much of the significance of the conference lies in its membership. As H.R.H. The Duke of Edinburgh put it in his Foreword to the Outline Programme of the Conference: "I cannot emphasize too strongly that this is a study conference not for research workers but for young people actually engaged in industry. Its main value will not be in the report of the speeches and discussions. Its value will depend upon what members make of what they see and hear. Its value will lie in the ability of the members to describe their points of view and experience for the benefit of others and their ability to distinguish what is likely to be useful in their own special cases. Ultimately it is hoped that the members will be able to extend their influence in their own countries and industries to the end that industrial enterprises are so organised that they form an integral part of a happy and healthy community."

Institute of Ceramics

OVER the years there has been a growing realisation of the underlying unity of the three major branches of ceramics: pottery, refractories, and heavy clay. Potting and brickmaking are among the oldest of man's achievements and pursuits, and the fascination of clay and the usefulness of its products have been and are still increasing. Moreover, the demands of our civilisation pose problems, the solution of which has given rise to new techniques of production and the development of new materials, and the research that is undertaken in connection with each of the three fields underlines their inter-relationship.

But, despite the achievements of the three industries, the extending of their horizons, and the high level of skill and knowledge upon which they depend, it is only as recently as May 6th, 1955, that ceramics in this country has been accorded formal recognition as a profession, by the incorporation of Institute of Ceramics, Ltd., which can give expression to the corporate views of its member ceramists, and offers to all engaged in ceramics a professional qualification of repute and authority.

The suggestion that such an Institute would be desirable had been made before the War, but at that time no steps were taken towards its realisation. Once matters had begun to return to normal again after the War, the suggestion was heard again; this time however with greater enthusiasm and more widely. As a result, the British Ceramic Society decided to take the lead in sounding the opinion of such organisations as might be interested in and support a professional institute for ceramists. An exploratory meeting was held, and the verdict was unanimously in favour of setting up a representative committee to examine the possibility of forming such an institute. The British Ceramic Society therefore appointed representatives to serve on the committee, and invited the following to do likewise: the British Pottery Manufacturers' Federation; the National Federation of Clay Industries; the Institute of Clay Technology; the Refractories Association of Great Britain; and the Institute of Clayworkers.

This committee met on a number of occasions and, with legal assistance, drew up a Memorandum and Articles of Association and By-laws for the projected Institute of Ceramics. With the preliminary stages in the formation of the Institute completed, the names of a number of Founder Fellows were suggested, and, in anticipation of events, they held a meeting at which an Interim Council was elected from among their number. The Council consisted of: Dr. A. T. Green, O.B.E. (*President*), Mr. T. G. Boxall, Mr. L. Bullin, Mr. B. Butterworth, Mr. F. H. Clews, Mr. R. Spencer C. Copeland, Mr. T. C. Edwards, Dr. W. L. German, Mr. G. N. Hodson, M.B.E., Mr. J. Stanley Jones, Mr. R. A. Kirby, J.P., Dr. H. H. Macey, Dr. J. R. Rait, Dr. G. R. Rigby, Dr. A. L. Roberts, Mr. P. B. Robinson, T.D., Mr. A. J. C. Watts, Dr. J. White, and Mr. N. Wilson.

On June 16th, 1955, this Interim Council was duly confirmed in office as the First Council of the Institute, and the following Officers were elected:

President:	Dr. A. T. Green, O.B.E.
Vice-Presidents:	Dr. W. L. German.
	Professor A. L. Roberts.
	Mr. G. N. Hodson, M.B.E.
Hon. Treasurer:	Mr. L. Bullin.
Secretary:	Mr. G. H. Stewart.

At the same time, the following were elected Honorary Fellows of the Institute, in recognition of their outstanding contributions to the several industries they have served for many years: Mr. H. Halliday, O.B.E., Col. H. Johnson, D.S.O., T.D., J.P., D.L. Mr. H. J. Plant, J.P. Mr. E. Simpson, Lt.-Col. C. W. Thomas, C.B.E., T.D. and Mr. F. West.

The Institute of Ceramics, Ltd., is constituted to serve the industries that it represents. As defined by the Articles of Association, its object appears to be manifold, but is, in effect, twofold—to establish and maintain among ceramic technologists the highest standard of professional conduct, and to improve the level of ceramic knowledge of those in or about to enter the ceramic industries.

Membership of the Institute, which is open to "citizens of the United Kingdom by birth, by descent, or by naturalization", is divided into three main classes:

(1) *Licentiates* (L.I. Ceram.). Those who, having a certain knowledge and experience of ceramics, have passed the Institute's prescribed examination or its equivalent, or are considered worthy of exemption by reason of their contribution to ceramic knowledge.

(2) *Associates* (A.I. Ceram.). Those who, having considerable knowledge of and experience in ceramics, have qualified as ceramic technologists by the Institute's prescribed examination or its equivalent, or have attained importance as ceramic technologists.

(3) *Fellows* (F.I. Ceram.). Those who, being fully qualified technically, are of established reputation in ceramics.

Details of the requirements of candidates for these three grades are contained in the By-Laws. It is appropriate to point out here, however, that the minimum age of acceptance, the minimum period of experience in ceramic science or practice of candidates, and the annual subscriptions, are as follows:

	Years of Age	*Period of Experience*	*Annual Subscription* £ s. d.	*Entrance Fee* £ s. d.
Licentiate	21	3 years	1 11 6	—
Associate	25	5 years	2 2 0	1 1 0
Fellow	Not nominally less than 32	8 years	3 3 0	1 1 0

The managing body is the Council, which, with effect from the Annual General Meeting of 1956, will consist of: the President, three Vice-Presidents, the Hon. Treasurer and twenty-four Ordinary Members of Council.

It has already been decided that the Council, acting in Committee, shall constitute the Nominations and Examinations Committee, to which will be submitted all applications for membership. Applications can be considered from those who wish to be admitted to one of the three grades of membership, on the basis of qualifications laid down in the By-laws, copies of which can be obtained from: The Secretary, Institute of Ceramics, Ltd., Federation House, Stoke-on-Trent, Staffs. In this connection a small sub-committee is drawing up a form of application for membership, which will be available in the near future, and will be sent to those who notify the Secretary in writing that they wish to apply in accordance with the By-laws. At the same time, this sub-committee is considering details in connection with syllabuses and other matters concerned with an examination system.

British Welding Research Association

Open Day at Abington Hall

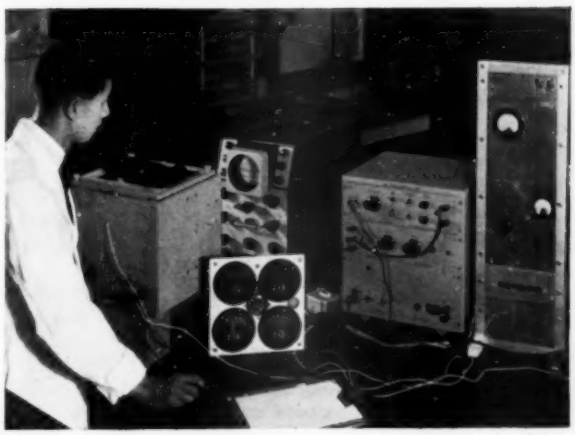
ONCE again the British Welding Research Association was favoured with fine sunny weather for its Open Day at Abington Hall, near Cambridge, and in such circumstances those participating must have enjoyed the beautiful surroundings to the full. The temperature was, perhaps, a little on the high side, and even the "top table" at the marquee luncheon was reduced to its shirt sleeves. The Chairman of Imperial Chemical Industries, Ltd., Dr. Alexander Fleck, had accepted an invitation to be the principal guest, but a summons to an investiture at Buckingham Palace, where he became Sir Alexander Fleck, made his visit impossible. Mr. Clifford Paine, Director of Research and Development to I.C.I., ably deputised and, in a very interesting speech, proposed the toast to the Association. Sir Charles Lillicrap, Chairman of Council, responded. In proposing the toast to the guests, Dr. J. H. Paterson, Member of Council, referred especially to a number who had given valuable assistance to the Association, including Mr. W. W. Watt, who replied to the toast.

"The primary object of an Open Day is, perhaps, to convince members that their money has been well spent, but there are other hardly less important objects, such as providing an opportunity for an exchange of views between the research worker and the user of the results of his research. The occasion also provides an opportunity for a man's work to be judged by his peers and, if found worthy, to be praised. And this is no bad thing for the man or for the Association. The satisfaction of a job well done and appreciated is a good spur to further progress." This quotation from the programme issued in connection with the Open Day puts the matter in a nutshell, and there is no doubt that the staff of the Association must have been greatly encouraged by the large attendance, and by the interest shown in the exhibits and demonstrations.

Metallurgical Researches

The metallurgical researches of the Association are undertaken in the laboratories at Park Crescent in London, which members had an opportunity of visiting last autumn. Individual researches were then on display, but at Abington a more general picture was given of the metallurgical programmes by illustrating aspects which are common to several of the researches.

The presence of hydrogen, mainly derived from the electrode coating, during the welding of steel can lead to defects in both the weld metal (fissures) and the parent plate (hard zone cracking), whilst in the case of aluminium alloys it can result in weld porosity and porosity in the heat-affected zone. An investigation is being made into factors controlling the incidence of fissuring in mild and alloy steel weld metal, and it has been shown that fissuring involves cleavage fracture and occurs during the cooling down of a weld within the temperature range 150–120° C.: the defect is largely eliminated by the use of low hydrogen electrodes. A study has also been made



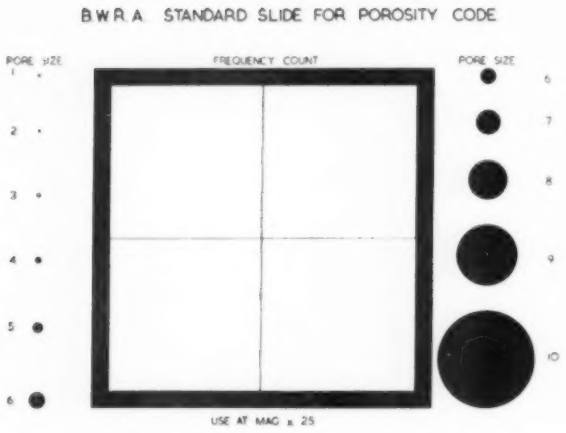
Equipment for recording heat flow measurements

of the effect of hydrogen on the yield point and strain ageing phenomena, while an extensive microscopical investigation has suggested that cleavage fracture occurs after slight plastic yielding, possibly resulting from the presence of hydrogen at interfaces in the ferritic matrix, or from the presence of an external load such as restraint.

The susceptibility to cracking in the heat affected zone of a welded high tensile steel depends mainly on the alloy content of the parent metal, the diffusible hydrogen from the weld metal, and the cooling rate of the welds, all of which factors are being studied. It is now possible to determine rapidly in the laboratory the continuous cooling characteristics of a given steel, and so to assess weldability, since the temperature of the end of transformation is related to the incidence of hard zone cracking under certain conditions. Recent work on specimens cathodically charged with hydrogen suggests, however, that transformation is not always necessary to initiate cracking, and that under certain circumstances hydrogen alone may produce cracking.

The problem of porosity in aluminium welding arises mainly in the metallic arc and self-adjusting arc processes, and available evidence suggests that hydrated corrosion products on the surface of the wire may be the main source of hydrogen for the former process. In the self-adjusting arc process the extent and nature of the porosity—whether it comprises a large number of fine pores or a small number of large pores—is also dependent on the welding conditions. By control of these, and of the wire treatment, it is possible to reduce the amount of porosity to a very low level, and to have this small amount present in a very fine state which is not detectable by normal radiographic methods. Work is under way on the effect of porosity on mechanical properties.

Equipment has been constructed for the estimation of hydrogen in both steels and aluminium alloys by the hot



The porosity code is a method of classifying and reporting severity of porosity in welds as observed in microsections

extraction technique, whilst the tin fusion method is being used for aluminium when the total hydrogen, i.e., intrinsic and surface, is required.

Many forms of cracking test have been devised to investigate the influence of filler or parent metal, and to compare welding procedures and processes, and those used or developed by B.W.R.A. were illustrated in the display. In the C.T.S. (controlled thermal severity) test, developed by the Association from the Reeve test and used in the investigation of hard zone cracking, the cooling rate can be controlled by varying the thickness of the plate and the fillet size. Hot cracking sensitivity, which is influenced by parent metal and electrode composition, is being determined by the Murex hot cracking machine, in which a fillet weld is made under controlled conditions whilst one test plate is rotated through 30° relative to the other.

Two cracking tests have been developed for use in connection with the welding of aluminium alloys. To assist in the development of improved metal arc electrodes for use in welding H. 10 (Al-Mg-Si) alloy, where cracking was experienced in the production of close-butt joints in thick plate, using aluminium–5% silicon electrodes, the slotted-butt test was developed. In this test a single rectangular plate of standard dimensions is used without external restraint, and containing a slot cut from the centre of a narrow edge and parallel to the long side. The welding current is adjusted to give full penetration and the desired amount of dilution. The degree of restraint decreases as the slot is lengthened, and several tests are made to determine the slot length at which cracking fails to occur.

A simple test, known as the "fishbone test," has been devised to investigate the effect of parent plate and filler metal additions on cracking during the argon arc welding of high strength heat treatable aluminium alloys. No external restraint is used, and the self restraint on the weld is progressively decreased by a series of slots at right angles to the weld—hence the name. The width of the test piece is chosen so that the crack initiated at the edge follows the weld due to thermal distortion. The length of the crack is a direct measure of the crack sensitivity.

In the self-adjusting arc welding of steels, now being investigated by the Association, one general problem is the occurrence of weld metal porosity resulting from a continuation of the steelmaking reaction

$$C + FeO \rightleftharpoons CO + Fe$$

and possibly to a lesser extent from entrapment of the shielding gas. A theoretical treatment has been made of the deoxidation reactions which could be utilised to prevent the reaction giving rise to the evolution of carbon monoxide and consequent porosity. The effect of welding conditions on dilution, penetration and wire burn-off rate has been investigated, using a commercially available filler metal, but arrangements have now been made for the preparation of a series of experimental filler metals.

It is intended to transfer the metallurgical work to Abington, and construction has started of new buildings for this purpose, and for much needed workshop, stores and welding shops. The total floor area will be 13,000 sq. ft.

Non-Destructive Testing

The work of the non-destructive testing laboratory is in the main concerned with the development of techniques for the ultrasonic reference block intended to act as a British and, possibly, as an international standard. The block is designed to serve the dual purpose of facilitating the adjustment of ultrasonic equipment, and of standardising on conditions of test, so that comparison may be made of weld testing results obtained by independent investigators. Two reference blocks, the other of Dutch origin, were on show, and comparisons of their capabilities are being made on behalf of a subcommission of Commission 5 of the International Institute of Welding.

The testing equipment available includes a Kelvin and Hughes Mark IV flaw detector, providing facilities for double probe longitudinal or shear wave inspection, and an Ultrasonoscope, which also provides single probe facilities with miniature probes. Most of the work on fillet welds has been done with a miniature 45° single probe, and demonstrations were provided on typical test specimens.

In conjunction with the fatigue laboratory, radiographic and ultrasonic inspection of butt welds in pipes is made before testing, for the purpose of correlating with the mode of failure. An idea of the correlation between radiographic and ultrasonic results was given by exhibits

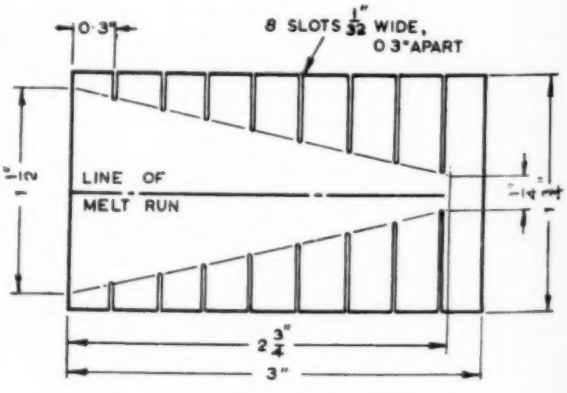


Diagram of the fish-bone test developed by the Association for the assessment of the weldability of high strength aluminium alloys

on show, and some of the special techniques developed for the ultrasonic inspection of Class A pressure vessel welds were demonstrated.

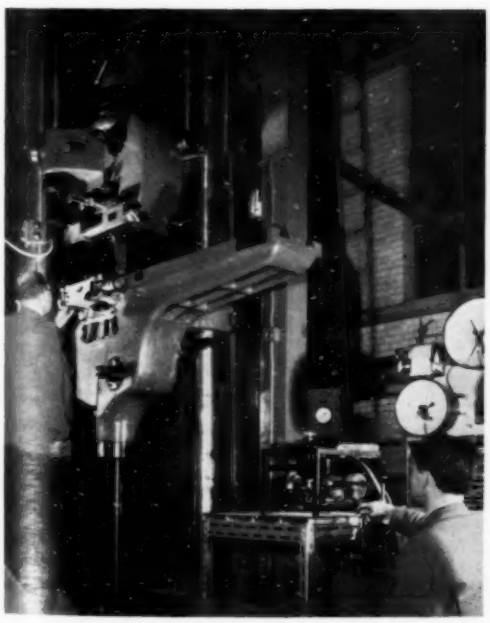
Other non-destructive testing techniques used at Abington include the magnetic method—which was demonstrated using both standard and fluorescent magnetic particles—the penetrant method, and radiography. The radiographic equipment available is only used on light alloy and very thin steel specimens because of its low energy characteristics, but the Radiographic Panel of the FE 18 Committee is actively engaged in considering ways of improving the quality of weld radiography.

A recent addition to the work of the laboratory is the testing of chains, for which it is hoped to develop an economic and rapid non-destructive technique. A series of experiments has been conducted by subjecting individual links to destructive tensile tests in an endeavour to correlate failures with defects in the weld zone, and macrosections of links so tested were on display.

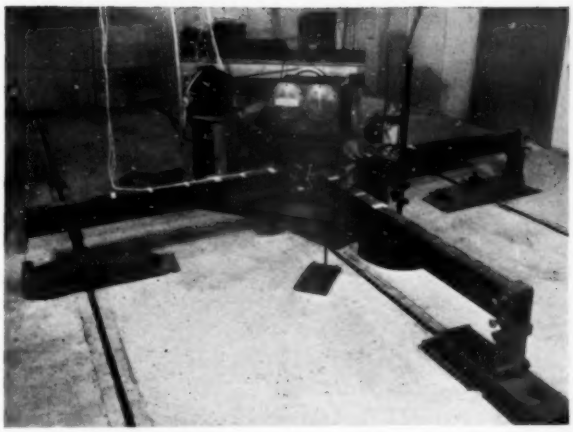
Fatigue Testing

The 100 ton hydraulic fatigue testing machine is used primarily for direct-stress fatigue tests on flat plate specimens up to a maximum thickness of 2½ in. and a maximum length of 6¼ ft. A programme of tests is in progress on butt welded ½ in. and 1¼ in. plates, which will later be extended to include the investigation of the influence of weld defects. Comparative tests are also being made on unwelded plates, with mill-scale on the surface and after it has been removed by machining.

Constant strain fatigue tests are carried out in a 100 ton simple lever machine. Using the first order lever system, with a lever ratio of 15 : 1, test loads up to 100 tons tension or compression can be obtained. Where smaller loads are required, the second order system can be used by mounting the specimen between the walking beam and the base of the machine ; in this way a greater dynamic stroke is available, and this is a useful advantage for testing flexible specimens.



Fatigue testing of thick plates containing metal arc welded butt joints, using 100-ton hydraulic testing machine



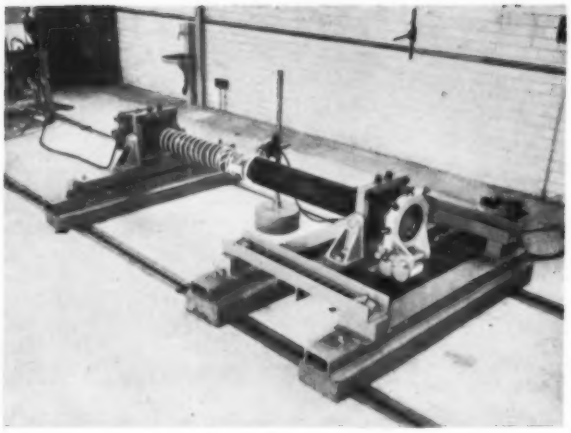
Resonance fatigue tests on cruciform sections used in automobile construction

An investigation of the fatigue strength of welded butt joints in 6 in. pipes is in progress, the main part comprising alternating bending tests carried out in a resonance vibration test rig. By choosing radiographically the diametrically opposed regions subject to the maximum stress, useful information can be obtained on the influence of weld quality. Four series of tests have been undertaken on deliberately faulty metal arc welds to determine the effect of lack of penetration, porosity, slag inclusions, and lack of fusion, respectively.

Specimens made from 16 s.w.g. deep drawing mild steel sheet, pressed and welded to form closed sections of the kind used in modern motor car chassis frames are being tested on a specially designed alternating torsion testing machine. Specimens of various designs are also tested in alternating bending about the major axis, and about the minor axis, of the rectangular sections, using a resonance vibration rig. The specimen is supported at the node positions for free-free vibration, and is excited at a frequency near to its natural frequency in bending by a mechanical oscillator attached to one end The bending amplitude can be measured, and the longitudinal bending stresses are determined by electric resistance strain gauges. Another application of the resonance vibration method was shown in which the specimens were thick-walled tubes with a welded butt joint at the mid-span position

A high pressure fatigue machine, designed in the Mechanical Engineering Department of the University of Bristol and installed by arrangement with Imperial Chemical Industries, Ltd., generates pulsating pressures of up to 20 tons/sq. in. The pressure is produced by moving a ram into the bore of the specimen and thereby compressing the fluid contained therein. The speed of operation is up to 800 cycles per minute, and the machine is being used for comparing various methods of welding thick-walled pipe.

For routine tests for the measurement of mechanical properties, and for notched bar tensile and bending tests in connection with brittle fracture studies, a 50 ton universal testing machine is available. It is also suitable for determining the tensile and shear properties of



Resonance fatigue testing of thick-walled tubes

resistance welds, and for the static loading of structural elements, when, for example, the measurement of strain distribution is undertaken.

Another universal static testing machine, of 200 tons capacity, is of the Baldwin-Tate-Emery single ram type, with tension and compression clearances of 6 ft., and fitted with a pressure cell for load indication by the Tate-Emery system. The test specimen shown in the machine was a gusseted pipe bend which had been loaded to collapse by moments acting in the plane of the bend and reducing the radius of curvature. Other tests undertaken with this machine include the determination of buckling loads of full-scale welded panels for railway coaches; stress analysis and strength tests on scale models of reinforced openings for storage tanks; and brittle fracture studies on steel plate.

Brittle Fracture in Steel

The mechanics of notch brittle fracture is being studied on 36 in. wide plates in a special static tensile testing rig designed by the Association's investigators and donated by a member. The apparatus is capable of exerting tensile loads of up to 600 tons on plate thicknesses up to 1 in. Broken test pieces were displayed to illustrate the results of work on $\frac{5}{8}$ in. plate specimens, on which investigations were made of the ability of steels of varying toughness to arrest running brittle cracks in comparison with the conventional riveted joint. Also exhibited were fracture surfaces from initiation tests on 1 in. plates, using sawcut notches in the prepared edges for a longitudinal central butt weld as crack starters. Weld stress relieving is one of the variables being investigated.

Fundamental work was illustrated by exhibits showing experiments on the geometrical size effect, and by the display of a high sensitivity 4-string catenary galvanometer used for surface energy measurements.

Pressure Vessels and Pipe Lines

The Association is actively engaged in work on the design and construction of welded pressure vessels and pipe lines, and in the laboratory concerned with these investigations, typical mechanical and electric resistance strain gauges were displayed. Tests have been carried out on a full scale 24 in. manhole opening, with plate reinforcement, attached to a specimen representing part of a cylindrical tank of 150 ft. diameter. A quarter scale model has also been tested and was shown along with another model provided with a different form of reinforcement.

In order to provide a datum with which future tests on fabricated bends can be compared, seamless welding elbows have been tested under fatigue loading. Three types of fatigue cycle have been used, namely, pulsating internal pressure, alternating external load, and alternating external load with the simultaneous application of static internal pressure. S/N diagrams for the three types of test were shown together with some typical fractures.

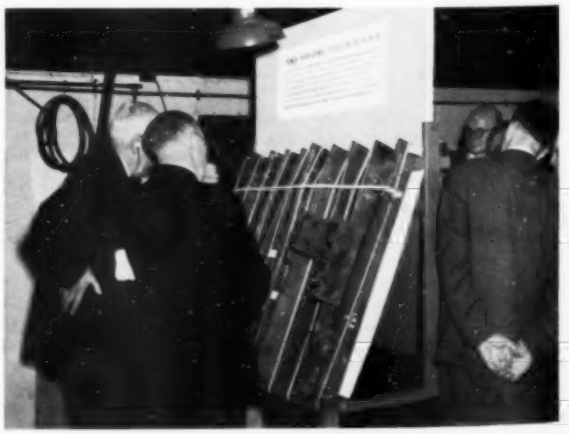
Tests have also been carried out on pipe bends built up from lengths of straight pipe, and nine pipe branch connections have been examined by experimental stress analysis in order to find a satisfactory type of reinforcement. An interesting display panel covered the progress of the work on the reinforcement of branch connections in pressure vessels, and a series of models illustrated the next stage of the stress analysis work, which is concerned with thicker vessels. An experimental pressure vessel shown had five branches reinforced in various ways, and a sixth with a novel type of reinforcement which is being assessed.

For generating pulsating internal pressure in vessels at a speed of up to 100 cycles per minute, a plant is available in which the pressure limits are continuously variable between zero and 6,000 lb./sq. in. A model illustrated, by means of a succession of electric lamps representing the flow of fluid, the principle on which the pulsating pressure plant operates.

Specimens liable to fracture violently can be placed in a test pit and completely covered with concrete blocks.

Oxygen Cutting

Static exhibits were used to indicate the lines of early work on iron/oxygen combustion fundamentals, and on pre-heat flame efficiency, and the results of calorimeter measurements of the "heat balance" conditions in typical plate cutting were shown. Flame radiation has been estimated by means of a thermopile, to determine



Sir William Larke (left) and Dr. H. G. Taylor, Director of Research, (right) examining specimens showing various lengths of running brittle cracks. These specimens were broken on a special tensile testing rig capable of exerting loads up to 600 tons on plate thicknesses of 1 in.

its importance, relative to convection, in flame/plate heat transfer.

Typical experimental cuts with cylindrical nozzles of various sizes were exhibited, showing the surprising similarity in result, despite wide variation in nozzle size and pressure. In cutting preheated plates, considerable speed increases are possible with normal surface heating flames. It is possible to maintain a cut in small preheated specimens with cutting oxygen alone. A new apparatus, which was shown in the development stage, is being designed to cut small annular specimens with oxygen only, to study combustion conditions without the complication of flame or arc.

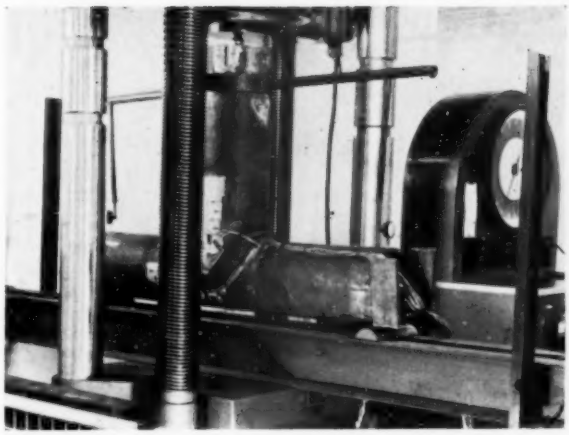
Resistance Welding

The main emphasis of present research work in spot welding is the application of the process to the joining of hardenable steels. The work is being done on a 100 kVA. spot and projection welding machine, with the aid of a seven-stage timer, which controls the duration and, by phase-shift, the heat of the initial welding current and of three post-heat stages. It also controls the duration of the " cool times " between the four " heat " stages. The 100 kVA. machine is also being used for welding $\frac{5}{16}$ in. bolts to sheet or plate up to $\frac{1}{2}$ in. thick ; for obtaining multiple projection welds in sheet material up to 14 s.w.g.; and for welding bosses with annular projections to sheet.

A three-phase frequency changer spot welding machine is capable of spot welding up to $2 \times \frac{3}{16}$ in. aluminium alloy sheets to the standards required for aircraft primary structures. Each phase-to-phase voltage of the three-phase supply is connected to a separate circuit comprising a pair of ignitrons and a transformer primary. One ignitron of each pair is made conductive, and hence the current in the three primaries is in the same direction at any instant. Magnetic flux in this direction is produced in the core, the increase in flux generating an e.m.f. in the single secondary winding, and causing a flow of direct current through the secondary circuit. For the next weld, the other ignitron of each pair conducts, and the secondary current pulse is in the opposite direction. The value of the secondary current is controlled by a phase-shifting device. By decreasing the off-time between successive D.C. impulses to the minimum the effect of continuous weld current can be obtained when larger heat times are required than can be obtained with one pulse. The maximum length of pulse which can be obtained is governed by the time taken for the core to become saturated.

Other welding machines available include a condenser discharge spot welding machine used for spot welding aluminium alloys up to 2×16 s.w.g. ; a single-phase 25 kVA. unit used for spot and projection welding of steel ; and a 5 kVA. bench machine which can be used for welding fine wires to thin sheets.

A Class 8990 Type EWG-2 up-and-down slope control unit recently acquired by the Association provides a means of controlling the rate of rise and fall of the welding current, and also its maximum and minimum values. The rise to or the fall from, full current can be adjusted within the range 1 to 30 cycles, whilst the weld heat time can be controlled from 3 to 120 cycles. Another new item of equipment is a NEMA N2 Class 8992 Type BCG-1 combination welder control—a four-stage sequence timer comprising control of squeeze time (3–120 cycles), weld time (2–120 cycles), hold time (1–50 cycles), and off-time (2–120 cycles).



Loading test on pipe junction with reinforcement

C.R.O. recording equipment, designed for recording secondary current and electrode force, has also been used in conjunction with a torsion testing machine to record the applied torque and the angle of twist to failure of the specimen. Other ancillary equipment includes a cycle counter in which scale of ten counting valves are used to indicate the duration of the welding current, and a pen recording instrument which is useful in providing an immediate record of weld and post-heat times, with some indication of current amplitude.

Coke Oven and By-Product Plant

A CONTRACT worth more than £2,000,000, for the construction of a new coke oven and by-product plant at Murton has been awarded to Woodall-Duckham Construction Co., Ltd., by the Durham Division of the National Coal Board. The Board themselves will shortly commence site clearance work and the project is scheduled for completion by September, 1958. The new plant will be an essential part of the Board's scheme for a combined mine where coal from Murton and Eppleton Collieries, and ultimately from Elemore, will be drawn up the new Hawthorn shaft now in process of sinking.

There will be 50 ovens of the same type as those put into operation at Fishburn a year ago. The new ovens will handle 1,000 tons of coal a day—all drawn at the combined mine and cleaned at a washery which is to be built nearby. Thus by 1959 East Durham will be producing further quantities of very high grade metallurgical coke, developments made possible by the existence of high volatile and low volatile coals close together. The entire scheme will result in the more efficient and economical winning, upgrading and processing of the remaining valuable coal reserves in this area.

The new coking plant will be capable of producing 250,000 tons of coke yearly as well as $7\frac{1}{2}$ million cubic feet of purified gas daily for the gas grid. This daily gas output will be roughly equivalent to a 24-hour supply for an industrial town of the size of Blyth or West Hartlepool. By-products will include sulphate of ammonia, tar and more than 1,000,000 gallons of crude benzol annually.

New Turkish Slabbing and Blooming Mill

Brightside Complete 34 in. Mill for Karabuk

ORIGINALLY designed by Brasserts, the Turkish Iron and Steel Works at Karabuk has undergone several expansions since it first commenced operation in 1940. The plant comprises coke ovens, two blast furnaces, four open hearth furnaces, heavy, medium and small rolling mills, a pipe foundry and the usual ancillary services. After an initial period of training under British staff, the running of the plant has been almost entirely in the hands of Turkish nationals.

Further expansion is in progress under the control of Sümerbank General Directorate, which has provided finance for many Turkish national enterprises. The International Construction Co., Ltd. (London), are the consulting engineers for the extensions, which include the installation of a 600-ton inactive mixer in the melting shop, the provision of a new battery of gas-fired soaking pits and of a new 34 in. slabbing and blooming mill, and the modification of the 28 in. mill. The contract for the slabbing and blooming mill plant, which is expected to have an output of 400,000 ingot tons per annum, was obtained by the Brightside Foundry and Engineering Co., Ltd., in the face of world-wide competition. The plant was recently completed at the company's Ecclesfield Works, and the following description is illustrated by photographs taken in the erection shops.

The output figure of 400,000 tons per annum is based on the mill operating 16 shifts per week and 50 weeks per year, rolling ingots having a weight of 3 tons—20½ in. mean square for the production of blooms, or 35 × 12 in. for the production of slabs. The bloom sizes will range from 12 in. square maximum to 6 in. square minimum, and slabs will be rolled up to 30 in. wide × 5 in. thick. There may later be a change to 5½ ton ingots, rolled to blooms bigger than 6 in. square, when an appreciably increased output is likely.

The equipment supplied by the Brightside Foundry & Engineering Co., Ltd., comprises the approach, working and runout tables; the 34 in. mill and drive, with side-guard manipulators; an ingot weighing and turning device; a hot cropping and dividing shear with stop and measuring gear; a slab pusher and transfer bed; and the tables and transfer gear for feeding the blooms, either direct or via a wash heating furnace, to the existing 28 in. structural mill.

Mill and Roller Tables

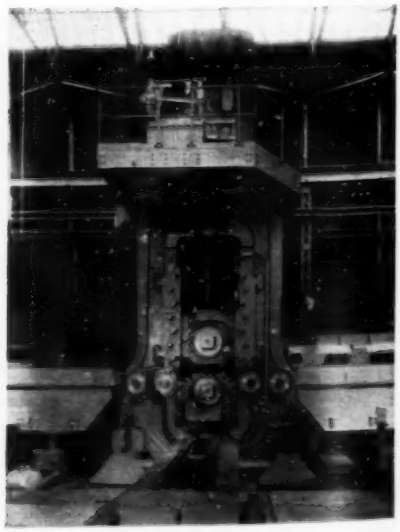
All the roller tables are group driven through mitre gears and line shafts, and have forged or cast rollers, according to the duty or the position in the plant. These table rollers and drives run in roller bearings throughout, and are of frame and unit construction.

On the approach table preceding the 34 in. mill is an overhead ingot weighing device fitted with an automatic weight recording unit. The weighing machine is incorporated in the lifting and turning unit which will allow the ingot to be presented to the mill either large or small end foremost, according to requirements. This unit is controlled from an operating pulpit located adjacent to it.

The mill train has 36 in. diameter rolls, 84 in. long in the barrel, running in fabric bearings lubricated by water and driven, through universal spindles and 41½ in. centres pinion housing, by a D.C. reversing motor having a working peak of 14,000 h.p. at 60 r.p.m., and a cut-out peak of 16,100 h.p. at the same speed. The speed of the mill is 0/60/150.

The rolls have a maximum lift of 36 in. and are powered to give a screwing speed of 160 in./min. The top roll is balanced by opposed screws and is provided with Brightside patent quick release gear to facilitate roll changing. Both rolls are changed simultaneously and are withdrawn

General view of the mill from the outgoing side.



End view of the mill.

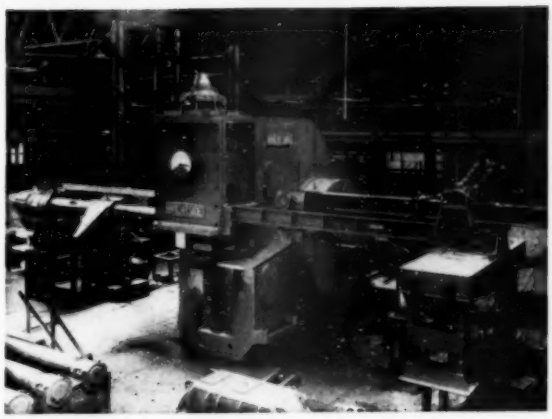
from or entered into the mill by a power operated sledge.

The manipulators are of the full sideguard type, and are fitted with tilting fingers on the ingoing side. These manipulators are designed to handle all products down to 6 in. square minimum, from the 20½ in. mean square ingot, and all sizes of slabs produced by the mill. They are powered to give a traversing speed of 164 ft./min. and incorporate patented tilting finger drive.

Bloom Shear

The hot bloom shear, which is of the down adjusting, upcutting type, is electrically operated and powered to give a blade load of 800 tons, and has a maximum daylight between the blades for accepting 12 in. high blooms, and a blade length suitable for 30 in. wide slabs. It is equipped with a crop end pusher for the discharge of the end pieces, and a retractile roller to permit such crops to drop freely into the collecting bins via a chute and butterfly switch. The stop and measuring gear is electrically operated for both lifting and traversing, and is calibrated to measure blooms from 1·25 metres minimum to 5·5 metres maximum.

Located immediately behind the shear is a pusher and transfer bed for slabs. The runout table from the shear is so located that the blooms can be delivered direct to the 28 in. structural mill or can be side transferred on a skid bed and charged in a wash heat furnace, being removed therefrom and delivered to the 28 in. mill via tables and transfer gear.



Hot bloom and slab shear, showing stop and measuring gear and crop-end pusher.

Combination Bar and Continuous Rod Mill Project

Samuel Fox & Co., Ltd., of Stocksbridge, near Sheffield, a branch of The United Steel Co., Ltd., are to spend nearly £2½ million on a new combination bar and continuous rod mill and associated bar heat treatment plant. Completion of the project is expected in two years time. Provision is being made in the initial layout for the erection of an additional mill and for the extension of the new bar treatment plant, should these developments be required at a later date.

The mill will roll bars and rods in alloy, high carbon and stainless steels from 0·212 in. to 2½ in. diameter, and equivalent sizes in squares and other sections, including spring flats. Essentially a high quality installation designed for maximum flexibility of operation, it will reduce normal re-rolling defects such as seams, laps and decarburisation to a minimum. Intended to replace an existing looping mill and a 14 in. double-duo mill at the Stocksbridge works, the new bar and rod mill is being supplied by The Brightside Foundry and Engineering Co., Ltd., Sheffield.

Billet Heating

Billets destined for rolling in the mill will first be charged into an oil-fired heating furnace of 25 tons per hour capacity, and of the continuous pusher type. Complementary batch furnaces will provide heating facilities for special qualities of steel, without interrupting production from the continuous furnace.

Rod and Bar Mill

The first section of the mill will consist of a three-stand 18 in. mechanised roughing train, with two stands three-high and the third stand two-high, all driven from one 1,500 h.p. A.C. motor. This will be followed by a 14 in. single stand two high mill, with a 350 h.p. D.C. variable speed motor.

Four 11 in. two-high stands arranged in pairs will form the intermediate train, each stand being driven by a 350 h.p. D.C. motor. Next will come an 11-14 in. cross-country mill of four two-high stands, with individual 350 h.p. D.C. motors to each stand, as in the intermediate train. When rolling bars, the 14 in. stands will be used for the larger sizes and the 11 in. stands for the smaller sizes. All sizes of bar will be delivered in straight lengths to a cooling bed and two bar reels will be available to coil all sizes up to 1 in. diameter or equivalent. When rolling rod, the 11 in. stands will be used as an intermediate train, delivering the material to the continuous finishing train.

This continuous finishing train will consist of a six-stand alternate vertical and horizontal 10 in. mill, designed for rolling all rod sizes. The train will be furnished with rod reels, the finished coils being delivered on to a system of cooling conveyors common to the bar reels. This mill will be equipped with 250 h.p. D.C. motors to each stand, and will be capable of rolling at speeds in excess of 3,000 ft. per minute.

All the electrical equipment for the complete mill installation is being supplied by Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester.

Bar Heat Treatment

In the bar heat treatment section of the new plant, facilities will be available initially for the annealing and heat treating of 14,700 tons of material per annum. Equipment to be installed includes two furnaces to ten tons capacity and four of four tons capacity, the latter being served by a floor type charging machine. Coke oven gas firing will be adopted, with the exception of one of the four-ton furnaces, which will be electrically heated. Oil and water quench tanks, and straightening, reeling and shot blasting equipment will be among other facilities in this section, where bars will also be cut to length and inspected prior to despatch.

Metal Coatings on Steel in Contact with Aluminium Alloys: Some Comparative Corrosion Tests

By S. C. Britton and R. W. de Vere Stacpoole

The Tin Research Institute

Steel nuts and screws coated with zinc, cadmium or tin-zinc alloy have been exposed, in contact with five aluminium alloys, to suburban and industrial, marine atmospheres, to intermittent immersion in the sea, and to salt spray in the laboratory. Considering long term protection of the steel and aluminium, tin-zinc is the most useful general purpose coating of the three. Electrode potentials of single metals in chloride solutions were not very helpful in predicting the performance of bimetallic couples, but measurements of the current flow between the two metals gave useful results.

SUITABLY chosen aluminium alloys have a corrosion resistance sufficient to permit them to be used unpainted in some outdoor structures. However, the frequent need to use some steel components, notably bolts and screws, in a structure otherwise of aluminium alloy, introduces a possibility of accelerated corrosion at contacts between the two metals. When the risks of such action cannot be made slight by suitable design, the application of a protective coating must be considered, and the use of a metal coating of adequate protective value on the ferrous components is the most attractive method. Such a coating would avoid the necessity of painting the whole structure, and would avoid the impairment in appearance of a structure caused by the local painting of areas in which bimetallic contacts occur.

Stainless steel or mild steel carrying a chromium coating has sometimes given good service[1] in contact with aluminium alloys, but some corrosion of the light metal may occur. Hot-dipped zinc coatings on steel have also been found useful[2], but the zinc is liable to be removed relatively quickly at contact with aluminium, and corrosion of the aluminium may then be stimulated by the exposed steel[3].

Coatings of electro-deposited tin-zinc alloy containing 80% tin, although able, like zinc coatings, to protect steel exposed at pores in the deposit, sometimes have an electrochemical behaviour intermediate between those of tin and zinc. It seemed possible that such coatings might be able to protect steel in contact with aluminium without being consumed as rapidly as are zinc coatings. The alloy is easily deposited from an alkaline zinc cyanide/sodium stannate bath and has already had a wide commercial application as a protective, easily solderable, coating. The deposit throws well into recesses and has a good bearing surface; it is thus well suited for use on screws, bolts and nuts. Tests have therefore been carried out in which steel screws, nuts and washers, electroplated with tin-zinc alloy, zinc, or cadmium, have been exposed in contact with several aluminium alloys in a variety of corrosive environments.

EXPERIMENTAL

Materials

Screws and Nuts.

The thickness of coating that can be applied to a threaded article is limited by the tolerance of the threads. In preliminary experiments, the maximun coating possible on normal commercial nuts and screws, 0·25 mil.* was found inadequate to secure protection for more than a year or two in even moderately corrosive environments. Means of applying a greater thickness were explored.

Screw blanks were plated before threads were cut or rolled, in the hope that the heavier coating on the head thereby made possible would protect the portion of the bolt in contact with the aluminium alloy, and that sufficient coating would remain on the threads to protect them in their less vulnerable position. It was found that very little coating was retained on the threads.

Other screws had their threads cut under-size to make possible the deposition of coatings 0·5 mil. thick without impairing the running of nut on screw. This method and coating thickness, applied to $1\frac{1}{4}$ in. $\times \frac{3}{16}$ in. hexagon head Whitworth set screws fitted with one washer and a nut, were adopted for the main tests. Some variants were retained to a minor extent and the full list of screws tested is as follows:—

Group X.—Standard-size screws plated directly with 0·25 mil. tin-zinc, zinc or cadmium. (Used in preliminary tests only.)

Group Y.—Standard screw blanks plated before cutting the screw thread with 0·5 mil. tin-zinc, zinc or cadmium.

Group Z.—Screws with Whitworth threads reduced to permit plating with 0·5 mil. tin-zinc, zinc or cadmium. When finished they were of standard size.

Group Z1.—As Group Z, but B.S.F. threads.

Aluminium Alloys.

Preliminary tests were carried out with one alloy, but for the main series of tests, a representative range of 5 alloys, in the form of sheet 0·048 or 0·064 in. thick, was studied. They were all tested with surfaces "as received." The full list of materials with designation as prescribed by B.S. 1470 : 1948 and an indication of the more important alloying elements, is as follows:—

S1C–H.—Commercial purity aluminium; hard condition. Thickness, 0·048 in.

NS6–H.—5% magnesium alloy; hard condition. Thickness, 0·048 in.

HS10–WP.—Magnesium-silicon-manganese alloy; fully heat-treated. Thickness, 0·048 in.

HS15–W.—4% copper-magnesium-silicon-manganese alloy; solution treated. Thickness, 0·064 in.

HC15–WP.—As HS15, but clad with pure aluminium; fully heat treated. Thickness, 0·064 in.

Steel panels electroplated with coatings similar to those on screws in contact with them were also exposed

*1 mil is 0.001 in.

in order to provide a standard of comparision by which any effect of contact with aluminium alloys on the lives of the coatings might be assessed.

Methods of Test

The panels were drilled with the appropriate number of $\frac{1}{4}$ in. holes into which the plated screws were inserted and fixed in position by plated nuts and washers; the nuts were tightened firmly, but not sufficiently to indent the aluminium alloys, with a spanner. The screws and nuts in contact with any one panel carried the same coating.

For exposure to the weather and to intermittent immersion in the sea, three panels (12×8 in.) of each aluminium alloy, one for each of the coatings on screws, were placed at each of four sites. Every panel carried seven screws, one of Group Y, five of Group Z and one of Group Z1. The screws were at least 2 in. apart.

In other tests, two specimens (4×3 in.) of each alloy were included for each of the coatings. Screws of Group Z only were used and two were fixed in each test panel. The tests carried out are set out below :—

(*i*) *Atmospheric Exposure.*

Panels were exposed to the weather at three sites, as follows :—

(*a*) *Suburban.*—The roof of the Tin Research Institute at Perivale, where atmospheric pollution is relatively low and is derived almost entirely from domestic fires. The test rack faces south.

(*b*) *Industrial.*—The roof of a laboratory in North London where atmospheric pollution is heavy. The test rack faces east.

(*c*) *Marine.*—A site facing south at Southampton Water. For the first 580 days the panels were exposed on the western side of the Water at an elevation of 50 ft., but were then transferred to another site on Hayling Island just above high water level.

At all sites the panels were held at an angle of 45° by porcelain insulators fixed on wooden battens. The heads of the screws were on the upward-facing surfaces.

(*ii*) *Intermittent Immersion in the Sea.*

Panels were held vertically in wooden frames underneath a jetty in Torquay Harbour at the mid-tide level.

(*iii*) *Salt Spray Test.*

Panels were exposed in a cabinet to a mist of 3·5% solution of sodium chloride for eight hours daily. They were allowed to dry off overnight and at week-ends and were washed down with a spray of distilled water before further exposure to salt-spray.

(*iv*) *Sea Water Immersion.*

Each panel was immersed vertically in one litre of natural sea water contained in a beaker. The panels were supported vertically in a slot cut in a Perspex block which rested on a level bed of washed silver sand. The area of aluminium within the slot was protected by chlorinated rubber paint.

(*v*) *Condensation Test* (*Suburban Atmosphere*).

Panels supported at their lower edge at an angle of 15° from the vertical, were exposed in a cabinet out-of-doors at Perivale. The cabinet allows free access of air but protects the specimens from direct weathering. Condensation seemed to occur uniformly throughout the cabinet, but to ensure equality of treatment, the position of the specimen racks was changed weekly.

(*vi*) *Electrochemical Measurements.*

Electrode potentials of the aluminium alloys and of the coated screws immersed in chloride solutions were measured with reference to the silver/silver chloride electrode. In addition, the current flowing between specimens of the alloys (exposed area, 6 sq. cm.) and coated steel (exposed area, 4 sq. cm.) when they were immersed in chloride solutions was measured. The two metals were short circuited except when measurements were made; then they were connected through a galvanometer of which the resistance, whether or not shunted to provide the required sensitivity, was 10 ohms.

RESULTS

Preliminary Tests

Tests carried out with coatings 0·25 mil. thick (Group X) on screws in one aluminium alloy (Mg, 1%; Si, 0·5%; Cu, 0·25%; Cr, 0·25%; fully heat-treated) showed tin-zinc to have considerable promise as a coating for the screws.

After 9 months in the industrial atmosphere (for these tests, at Oldham) or 15 months in the suburban atmosphere, the screws coated with zinc or cadmium were severely rusted and sheared when an attempt was made to remove the nuts, whereas screws coated with tin-zinc were only somewhat stained with rust and the nuts could easily be removed from them. Cadmium coatings deteriorated rather more quickly than zinc coatings. Slight special attack on the aluminium alloy in the vicinity of the screws followed the failure of the zinc and cadmium coatings.

The test in a marine atmosphere was stopped after 6 months before a decisive result was obtained. At this stage, small rust spots had appeared on the screws coated with tin-zinc; slight rusting of the zinc-coated screws had begun; the cadmium-coated screws were still rust-free, and no special attack of the alloy had developed near any of the screws.

In intermittent immersion in the sea or in salt-spray tests, tin-zinc coatings behaved rather better than either cadmium or zinc coatings. The tin-zinc coated nuts could still be removed easily, on surfaces only slightly rust-stained, when the nuts coated with zinc and cadmium were immobilised by heavy rusting. Moreover, local corrosion of the aluminium alloy occurred around the screws; this was, in the long run, far less for screws plated with tin-zinc than for those plated with zinc or cadmium.

Main Tests

Before entering on detailed descriptions of the results of the main tests, three points should be made clear. Firstly, although the coatings applied to the screws and nuts were all of the same nominal thickness, 0·5 mil., determinations of the actual thickness carried out on samples drawn at random from the stock of materials revealed some variations. The coating thicknesses found were as follows :—

Zinc Coatings : Group Z, 0·7 mil.; Group Z1, 0·3 mil.
Tin-Zinc Coatings : 0·4 mil.
Cadmium Coatings : 0·6 mil.

Secondly, the onset of rusting on the screws and nuts varied with the coatings. The tin-zinc coatings acquired comparatively early in the tests a light general rust-stain

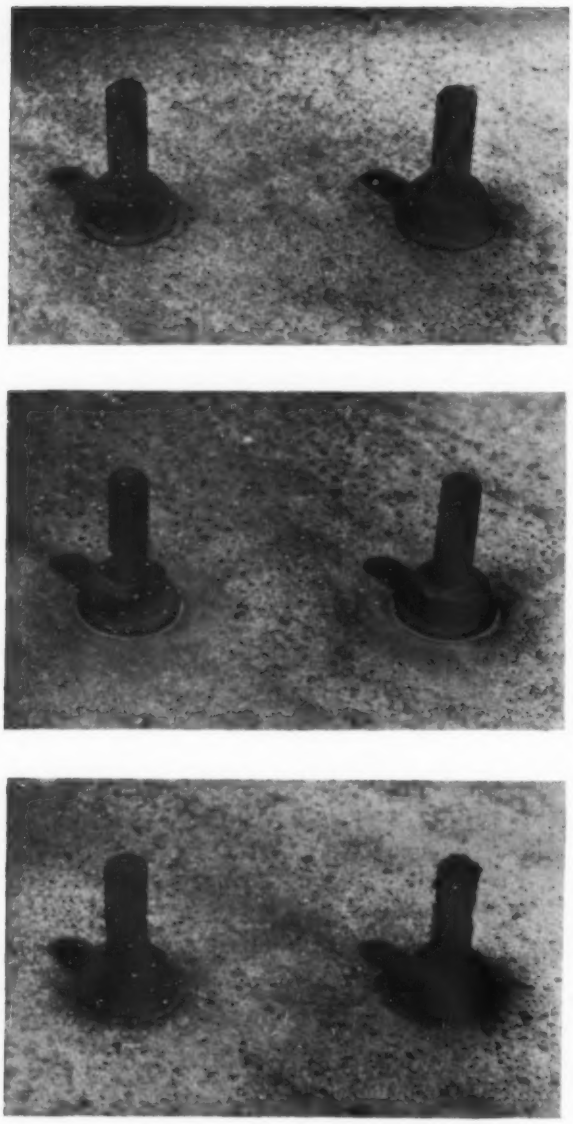


Fig. 1.—Plated screws and nuts in aluminium of commercial purity after exposure to suburban atmosphere for 974 days. The coatings are: upper pair—tin-zinc; middle pair—zinc; lower pair—cadmium.

with the surface remaining smooth and unspotted, and this remained for a very long period without a substantial change. On the other hand, when once rust appeared on screws coated with zinc or cadmium, further deterioration to the state when the whole surface was covered with loose rust was relatively rapid.

Thirdly, the threads cut in plated blanks (Group Y) rusted, for all coatings, in a few weeks, and further reference to these threads will not be made.

Atmospheric Exposure Tests.

These tests are still in progress, and in some instances complete rusting of the threads of the screws has not occurred. Considerable rusting has, however, taken place on all the screw-heads which are on the sides of the panels exposed to full weathering. The periods for which the coatings prevented free rusting are summarised in Table I.

TABLE I.—USEFUL LIVES OF COATINGS IN ATMOSPHERIC EXPOSURE TESTS.

Coating	Periods of Exposure (months) to Produce Free Rusting of Screw Heads and Screw Threads* at the Sites Designated.		
	Perivale (Suburban)	North London (Industrial)	Hayling Island (Marine)
Tin-Zinc	30 (more than 35)	33 (more than 33)	22 (more than 34)
Cadmium	6 (19)	5 (5)	34 (more than 34†)
Zinc (thicker coatings, Z)	24–30 (more than 35)	33 (more than 33†)	19 (16)
Zinc (thinner coatings, Z1)	13 (20)	14 (13)	8 (8)

* Figures in parentheses. † Some rust visible at 31 months.

At any one site, these periods were not greatly affected by the aluminium alloy with which the screws were in contact, except that screws in contact with alloy HS15 were consistently the first to show rust.

The full extent of the corrosion of the aluminium alloys will only be revealed when the screws are removed. At inland sites, corrosion around any screws so far appears to be relatively slight, although it is perceptible around all rusting screws. At all sites, in the early stages of exposure, an area of aluminium surrounding zinc-plated screws and, to a lesser extent, cadmium-plated screws was better preserved than the more remote areas of the panel. This protected zone was not observed near screws plated with tin-zinc, and, at the marine site, there appeared to be even a slight acceleration of corrosion near tin-zinc. The failure of a zinc or cadmium coating was, however, followed by a much more rapid attack of the aluminium than that observed around tin-zinc coatings that were still protecting the steel from rusting. It seems best from the practical viewpoint to judge the condition of the aluminium after at least the zinc and the cadmium coatings have failed. On this basis, tin-zinc appears much superior to cadmium and slightly superior to zinc in the inland exposures, and superior to zinc but slightly inferior to cadmium in the marine exposure. The condition of panels of commercial aluminium and representative screws after exposure at inland and marine sites is illustrated in Figs. 1 and 2, respectively.

In spite of the local protection given to the aluminium alloys by screws coated with zinc or cadmium, these screws rusted no more quickly in contact with aluminium alloys, except HS15, than when in contact with steel carrying the same coating as themselves. Probably the cathodic protection given by the aluminium alloy to steel delayed the onset of rusting when the coating had been destroyed, and thus obscured the effect of any accelerated destruction of the coating in contact with aluminium.

Intermittent Immersion in the Sea.

Observations during the test carried out at a mid-tide position were made difficult by some growth of barnacles on the test-panels. It was, however, clear that the zinc coatings permitted serious rusting of the screws long before the other coatings. The test was discontinued after 21 months. The zinc-coated screws were then all very rusty; the nuts on them were completely immobilised and the areas of aluminium alloy surrounding them were very severely corroded. Tin-zinc and cadmium coatings were in fair condition and the nuts could easily be removed, although some rusting of the screws in contact with alloy HS15 had occurred. Local corrosion

TABLE II.—CONDITION OF ALUMINIUM ALLOYS AFTER 650 DAYS' HALF-TIDE TEST IN THE SEA.

Alloy	General Surface	Near Screws Carrying the Coating Indicated		
		Tin-Zinc	Zinc	Cadmium
S1C ..	Few small pits	Some deep pits	Perforated at several places	As general surface
NS6 ..	Slightly darkened only	Some deep pits	Very severe pitting	No corrosion
HS10 ..	Few small pits	Deep pitting and two perforations	Perforated at several places	Very slight corrosion generally but one perforation
HS15 ..	Numerous patches deeply etched	Slightly increased corrosion	Slightly increased corrosion	No corrosion

of the aluminium alloys was rather severe at contacts with screws coated with tin-zinc, very severe near zinc-plated screws, but very slight around cadmium-plated screws, except that a pit formed under one cadmium-plated washer and had perforated a panel of the HS10 alloy. In this test, appreciable differences in behaviour among the various aluminium alloys were seen; these are summarised in Table II.

The condition of the panels of commercial aluminium (S1C) and typical screws at the end of the test is illustrated in Fig. 3.

Outdoor Condensation Test (Suburban Site).

After 850 days, only the cadmium plated screws were seriously rusted, although the tin-zinc coatings had carried a general light rust-stain from a very early stage. The tin-zinc coatings in contact with alloy HS15 and with steel plated with tin-zinc were appreciably more stained with rust than those in contact with the other alloys. The alloys, except HS15, had a very slight accumulation of corrosion product round the tin-zinc plated screws, and evidently were giving some cathodic protection to them. In this test, it has been difficult to assess the progress of corrosion around screws plated with zinc or cadmium, because hygroscopic corrosion products of the coatings formed a distinctive zone around each screw in which any corrosion product from the aluminium could not readily be seen. This zone of product was particularly clear around the cadmium coatings, for which it extended into streams passing down the panels. From observation of the uncleaned metal, it appears likely that some increase in corrosion occurs in this zone of persistent moisture.

After 850 days, the cadmium coating is undoubtedly the worst in this test. The relative merits of zinc and tin-zinc are not yet established, since the slight corrosion of aluminium near tin-zinc coatings might be quickly exceeded near zinc coatings once they failed.

Salt Spray Tests.

Although the tests of exposure to natural conditions are sufficiently far advanced to give some reliable results, the effects obtained in salt spray tests remain of some interest. They provide an illustration of the action to be expected when the bi-metallic assembly is wet for long periods by a chloride solution of high electrical conductivity, and also permit a judgment to be made of the value of this test for any further investigations in the same field.

The deterioration of the test-pieces progressed as it did in exposures to natural conditions, i.e., initially zinc and cadmium coatings gave protection to the steel screws and locally to aluminium alloys, whereas tin-zinc coatings protected only the steel, but, when any coating had ceased to be able to protect the steel components,

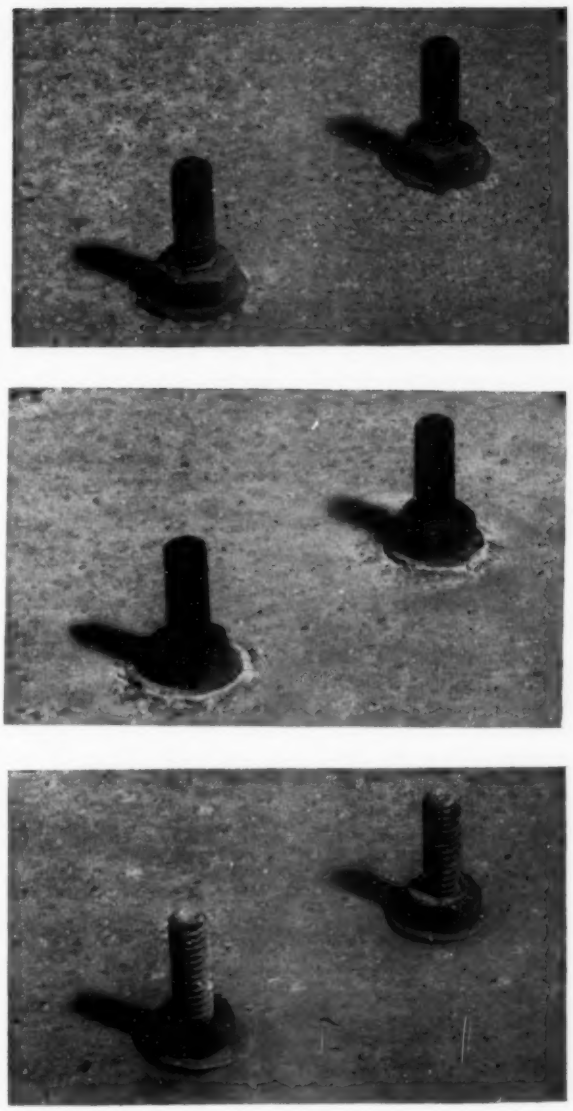


Fig. 2.—Plated screws and nuts in aluminium of commercial purity after exposure to a marine atmosphere for 684 days. The coatings are: upper pair—tin-zinc; middle pair—zinc; lower pair—cadmium.

corrosion of the aluminium alloys was severe and rapid. The zinc coatings ceased to protect in 40–80 days (160–310 hours' spray). Some cadmium-plated screws were rusting after 120 days (536 hours' spray) and all were rusted by the end of the test. Tin-zinc coatings were slightly spotted with rust after 99 days (420 hours' spray) but had suffered little further deterioration when the test was ended after 326 days (1,520 hours' spray). At this time, the nuts could easily be removed, whereas those coated with zinc were completely immobilised and those coated with cadmium could be removed only with great difficulty. As in the half-tide test, aluminium alloys varied appreciably in their behaviour; their condition at the end of the test is indicated in Table III.

In this test, there were indications that all the

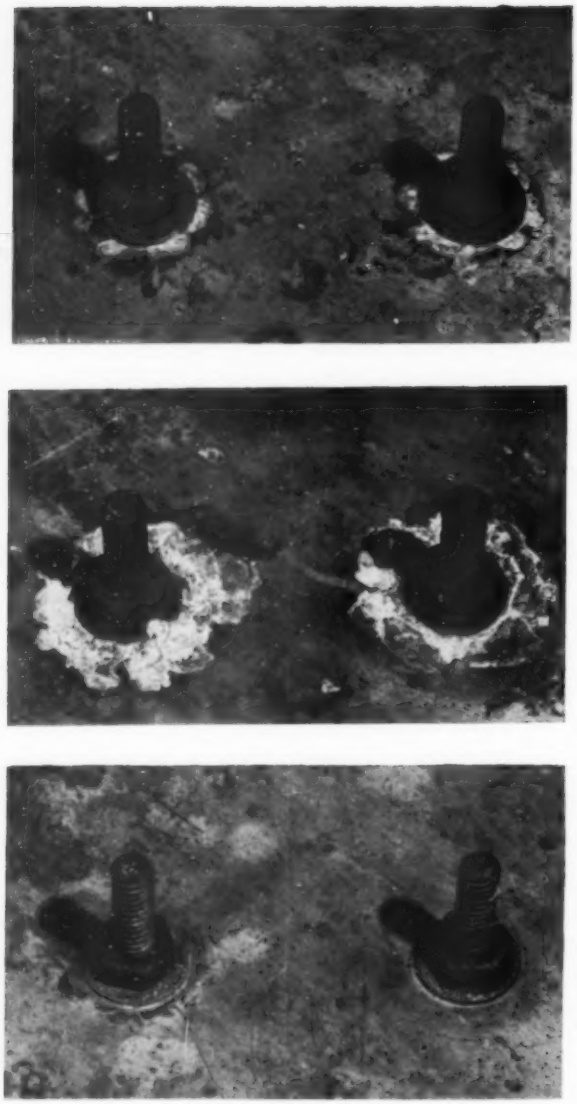


Fig. 3.—Plated screws and nuts in aluminium of commercial purity after exposure to the sea at mid-tide level for 650 days. The coatings are: upper pair—tin-zinc; middle pair—zinc; lower pair—cadmium.

aluminium alloys except HS15 gave some cathodic protection to the screws plated with tin-zinc.

The condition of some samples after removal of corrosion product at the end of the test is illustrated in Fig. 4. The results agree with those obtained in intermittent immersion in the sea, or in exposure to a marine atmosphere, in showing the weakness of zinc in saline conditions. The relative performance of cadmium and tin-zinc was, however, less favourable to cadmium in the salt-spray than in the natural exposures. The results differ considerably from those obtained in natural exposures inland.

Immersion in Sea-Water (Laboratory Tests).

The results obtained have differed somewhat from those obtained in other tests, in that some local corrosion of the aluminium alloys took place without prior rusting of the coated steel components. No doubt, in the conditions of the test, with a solution of high electrical conductivity which can deposit scale on cathodic areas, protection is given to the steel, even when the metal coating has been removed from it. In addition, the local corrosion of the aluminium alloy was not reproducible from screw to screw, and was probably stimulated by oxygen starvation at crevices under the screw-heads and washers, as well as by the bi-metallic contact.

Screws coated with tin-zinc and placed in specimens of HS15 or HC15 rusted locally after a few weeks, and cadmium-coated screws in HS15 began to rust at the area of contact with the light alloy after 22 weeks. No other rusting had occurred after 80 weeks, at which stage half the specimens were removed and cleaned. The zinc coatings had been entirely consumed and had been replaced by a hard scale; the tin-zinc coatings, except on the partly rusted screws, were in good condition, and the cadmium coatings had been largely removed. None of the alloys carrying zinc-coated screws was attacked near the screws, but alloy HS15 and aluminium of commercial purity (S1C) had pits under or near some screw-heads and washers plated with cadmium or tin-zinc alloy.

The samples remaining under test showed little further deterioration after a total of 820 days.

Electrochemical Measurements.

Measurements of electrode potential of single specimens of aluminium alloy or of plated steel, and of current flow in bi-metallic couples immersed in 3% sodium chloride solution, have given information which gives some help in interpreting the results of the exposure tests. The thickness of all coatings examined was 1 mil.

The potentials measured with reference to a silver/silver chloride electrode at 30° C. are shown in Table IV. These values are those recorded after immersion of uncoupled samples for 4 days. In general, there was little change after an initial period of a few hours, but the potential of steel coated with tin-zinc became more positive as immersion was prolonged; the initial and final values are quoted. Coatings of tin-zinc sufficiently thick to be pore-free retain a zinc-like potential for long periods in a neutral solution[4], although their potential may quickly approach that of tin if they are exposed to strongly acid media. In the experiments now described, the coatings were not pore-free, as was evidenced by the appearance of rust-spots, and the final potential measured resembles that of tin-coated steel. No doubt the surface became denuded of zinc in the initial stages when the pores were protected.

TABLE III.—CONDITION OF ALUMINIUM ALLOYS AFTER 316 DAYS' SALT-SPRAY TEST.

Alloy	General Surface	Near Screws Carrying the Coating Indicated		
		Tin-Zinc	Zinc	Cadmium
S1C ..	Severely pitted with some undercutting	Slightly intensified pitting	Very severe pitting	As for tin-zinc
NS8 ..	Slight pitting	Moderate pitting	Several perforations	As for tin-zinc
HS10..	Slight pitting	Slightly accelerated pitting	Several perforations	As for tin-zinc
HS15..	General etching	No special attack	More severe etching	Slightly more severe etching
HC15..	Slight corrosion	Skin removed under head of screw and general etching of exposed alloy	More severe etching than general. Widespread removal of skin and exposed alloy	Skin removed under and near screw-heads and washers with etching of exposed alloy

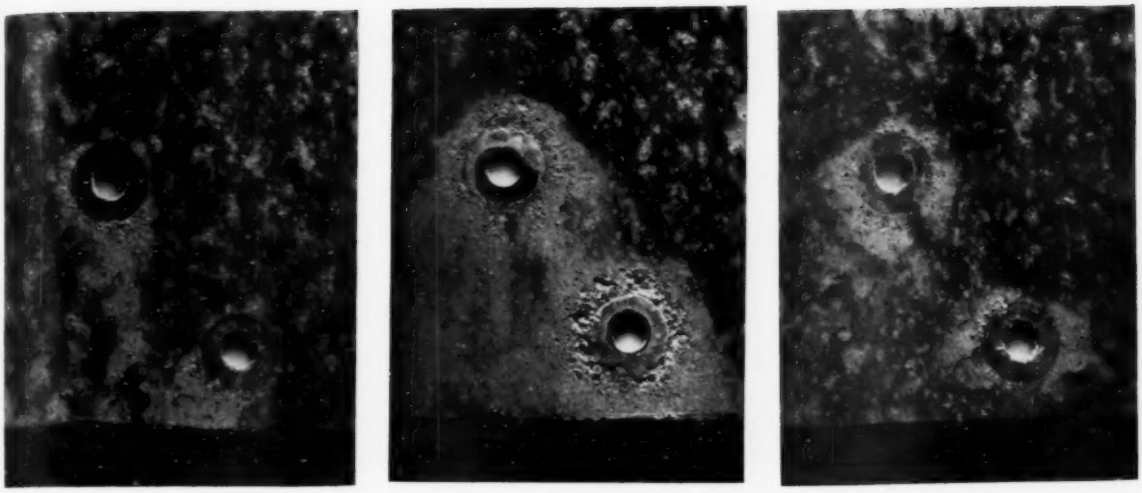


Fig. 4.—Commercial aluminium after exposure in contact with plated screws and nuts to laboratory salt-spray test for 326 days (1,520 hours' spray). Photographed after removal of corrosion products. The coatings on the screws were: left-hand panel—tin-zinc; centre panel—zinc; right-hand panel—cadmium.

Measurements of the current flowing in couples, each constituted of a piece of aluminium alloy and a steel rod, with or without a plated coating, immersed in 3% solutions of sodium chloride, gave results not altogether in accordance with the measured potentials of uncoupled specimens. With all the alloys except HS15, by far the largest currents observed were those flowing between steel and the aluminium alloy, with the steel cathodic. These were consistently around 100 micro-amp, whereas the currents flowing in couples with plated steel were generally not more than 10 micro-amp, and were often much less, although currents of up to 50 micro-amp were observed in the early stages of some experiments with zinc-coated steel.

Contrary to the indication of the potential measurements, cadmium coatings were slightly anodic to all the alloys after a few hours of rather unsettled behaviour, and the behaviour of tin-zinc coatings was not as indicated by either the initial or final values of their potentials. The polarity of coated or uncoated steel relative to any of the alloys except HS15 may be summarised as follows:—

Zinc-Coated Steel.—Initially anodic, but becoming cathodic after 20–40 days. The current after the reversal of polarity remained, however, well below that observed with bare steel for the whole of experiments lasting 80 days.

Tin-Zinc-Coated Steel.—Initially anodic, but becoming slightly cathodic after a few days.

Cadmium-Coated Steel.—Slightly anodic after a few hours' unsettled behaviour.

TABLE IV.—POTENTIALS WITH REFERENCE TO THE SILVER/SILVER CHLORIDE ELECTRODE OF METALS IMMERSED IN 3% SOLUTION OF SODIUM CHLORIDE AT 30° C.
(METAL COATINGS ALL 0·001 IN. THICK)

Electrode Material	Potential (Millivolts)
Steel with Zinc Coating	−1027
Steel with Tin-Zinc Coating	−1038 to −670
Aluminium Alloy HS10	− 946
Aluminium S1C	− 870
Aluminium Alloy N8	− 780
Steel with Cadmium Coating	− 740
Steel	− 700
Aluminium Alloy HS15	− 660

Bare Steel.—Strongly cathodic throughout test.

In couples with alloy HS15, only tin-zinc coated steel became slightly cathodic; even bare steel was slightly anodic after the first day, and zinc-coated steel remained consistently anodic, although the current declined very much after about 10 days' immersion.

The observations of current flow are qualitatively in reasonable accord with performance of the bi-metallic assemblies. Zinc and cadmium initially protect steel and aluminium, but when the coating is consumed, the aluminium is attacked where in contact with exposed steel. Tin-zinc, slightly cathodic throughout, never protects the aluminium alloy but itself receives some protection, so that the increase in current following removal of the coating is delayed.

Discussion

Perhaps the most important finding is that all the coatings applied, although thicker than is common practice for screws and nuts, had a relatively short life compared with that expected from aluminium sheeting or structural members. It is of course, in accord with experience that coatings 0·5 mil. thick should protect steel for only a few years, but it was disappointing that when a coating failed both the steel component and the aluminium should be corroded so badly in the more severe types of exposure.

The relative merits of the various coatings were not the same at all stages of the tests, but the early stages are of little practical importance. After nearly three years, the ultimate effects on the aluminium alloys of all the bi-metallic contacts are not established for all conditions, but they can be foreseen sufficiently well to draw tentative conclusions. The results obtained fall into two classes, distinguished by both the severity of corrosion of the aluminium alloys at contacts with steel, and by the relative performance of the coatings: those for marine environments, including salt spray, and those for inland exposures.

In marine environments, severe attack of the aluminium alloys developed in the neighbourhood of the screws, especially in the more continuously wet con-

ditions of intermittent immersion in the sea and in salt spray. There was no doubt that zinc provided the least satisfactory coating. The long-term difference between tin-zinc and cadmium coatings was small. In the preliminary tests with thinner coatings, tin-zinc appeared to be the better but, in the main tests, cadmium has been a little better, except in salt spray. By the time that the thicker cadmium coatings were corroded away, rather severe corrosion of the aluminium alloy had occurred around tin-zinc coatings.

In inland environments, the attack on aluminium alloys remained relatively small, no doubt on account of the lower conductivity and the relatively small chloride content of the moisture on the metal surface. Cadmium coatings were by far the least satisfactory, and there was not a great deal to choose between zinc and tin-zinc coatings. In the preliminary tests, with thinner coatings, the threads of screws coated with tin-zinc remained serviceable for longer than those of screws coated with zinc, and there is a strong probability that this result will also be obtained in the main tests.

It appears, therefore, that tin-zinc coatings, although not outstandingly the best in any environment, are always as good or nearly as good as the better of the others and, since they are appreciably better than zinc in marine environments, or cadmium in inland urban conditions, they may be regarded as the most useful general purpose coating of the three.

Tin-zinc secures its advantage by acting slightly cathodically to the aluminium alloys; the coating is preserved and although slight acceleration of corrosion of the aluminium may occur, the large acceleration which follows the failure of a coating on steel is deferred for a long time. Moreover, the formation of hygroscopic corrosion products is less marked on tin-zinc than it is on cadmium and zinc. The local ring of persistent moisture which results from the presence of such products was especially evident in the sheltered inland exposure, more particularly with cadmium coatings, but it may be expected to cause increased local corrosion in all environments except continuous immersion.

In previously reported[5] weathering tests of the three coatings applied to steel panels, tin-zinc proved appreciably superior to cadmium but inferior to zinc in inland exposures, a little inferior to either in a marine atmosphere, and superior to zinc but inferior to cadmium in intermittent immersion in the sea. Thus, in contact with aluminium alloys, the relative protective values of the coatings are changed somewhat in favour of tin-zinc, which has, however, generally a protective value comparable with those of zinc and cadmium. In exposure to atmospheric corrosion when sheltered from rain, tin-zinc coatings have been found, both in tests and in use, to be effective alternatives to cadmium or zinc. The suggestion of the use of tin-zinc as a coating for steel in contact with aluminium involves, therefore, not the production of a special coating for this purpose, but the extension of the uses of a coating which has already been shown to be valuable in other fields.

Summary and Conclusions

None of the three coatings tested gives protection for more than a few years when applied, in the thickness tolerable on small threaded components, to steel in contact with aluminium alloys. Coatings of zinc and cadmium protect both steel and adjoining aluminium until they are consumed. Thereafter, corrosion of the aluminium is accelerated, considerably in marine environments but only slightly inland, and some rusting of the ferrous component occurs. Tin-zinc coatings are slightly cathodic to aluminium alloys and, therefore, received some protection at the expense of a loss of aluminium which may be considerable in saline media.

The relative merits of the three coatings will not necessarily be the same for all conditions of service and for all thicknesses of coating, since much depends on whether an intolerable amount of corrosion occurs round a tin-zinc coating before the other coatings fail. In the present tests of coatings 0·0005 in. thick and aluminium sheets 0·048–0·064 in. thick, conclusions in regard to the long-term ability of the coatings to protect the steel component and to restrain accelerated corrosion of the aluminium alloy, may be drawn as follows :—

(1) In marine environments, coatings of cadmium or tin-zinc give much better service than coatings of zinc. Cadmium appeared to be inferior to tin-zinc in the most severe test-conditions of salt spray, but a little better in exposure to the atmosphere and distinctly better for intermittent immersion in the sea.

(2) In inland environments, coatings of zinc or tin-zinc give much better service than coatings of cadmium. There is little to choose between zinc and tin-zinc.

(3) Since tin-zinc was in all conditions never the worst coating, and was always never far inferior to the best, it may be recommended as a useful general purpose coating.

(4) In exposure to the weather, the aluminium alloys tested, with the exception of HS15, behaved rather similarly at contact with the ferrous metal. Alloy HS15 suffered comparatively little localised corrosion and this was true also of HC15, on which, after perforation of the surface skin, attack spread out instead of penetrating further into the exposed alloy. In the more severe conditions of intermittent immersion in the sea, the alloy NS6, containing 5% magnesium, was a little less attacked than other alloys.

The results of salt-spray tests differed very considerably from those obtained in natural exposures inland, but were in fair agreement with those obtained in exposures to a marine atmosphere or to intermittent immersion in the sea. Measurements of electrode potential did not predict satisfactorily the behaviour of the bi-metallic assemblies, but measurements of current flow between two metals appeared to be useful at least in predicting qualitative behaviour.

Acknowledgments

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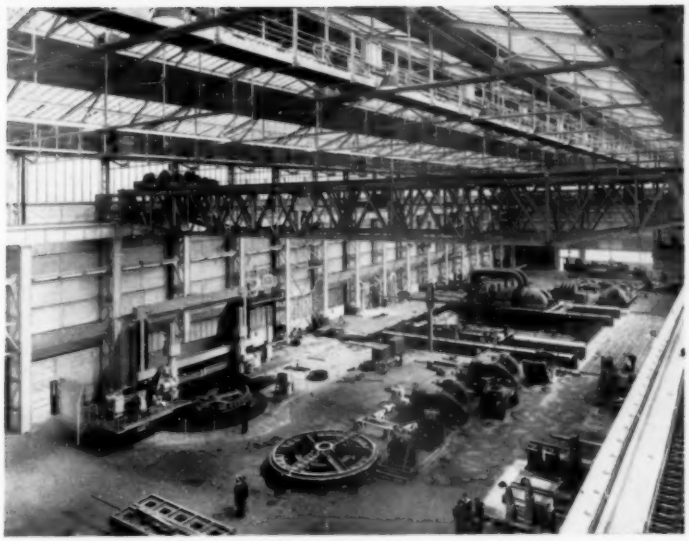
New Heavy Turbine Production Facilities for G.E.C.



An interior view of the new heavy turbine shop showing the Froriep 26 ft. vertical boring and turning mill in left foreground.

A NEW heavy turbine shop, designed for the erection and testing of the largest machines at present envisaged for power generation, was opened on July 15th, 1955, at the Fraser & Chalmers Engineering Works of The General Electric Co., Ltd., at Erith, Kent. The opening ceremony was performed by the Rt. Hon. Lord Citrine, P.C., K.B.E., Comp.I.E.E., LL.D., Chairman of the Central Electricity Authority.

Since the war there has been an increasing demand for electrical power in all parts of the world, and a trend towards the use of turbo-alternator sets of higher individual capacity. The new shop has therefore been designed to increase substantially the manufacturing capacity of the Fraser & Chalmers Engineering Works, and to provide facilities on the necessary scale for building machines up to ratings as high as 400 MW when required in the future.

The new shop has a main bay 364 ft. long and 131 ft. wide, with a machine tool annexe on one side measuring 284 ft. by 40 ft., making a total floor area of 59,044 sq. ft. In the main bay the height to the eaves is 59 ft., and in the annexe 37 ft. The height to the apex of the roof in the main bay is 82 ft. Two 60-ton Wharton cranes with a span of 120 ft. run on rails extending the full length of the shop at a height of 43 ft. : they can be operated in tandem for a lift of 120 tons. In addition to the 60 ton main hoist, each crane has a 20 ton auxiliary hoist.

Test Bed

The pit on which turbines are erected and tested is 91 ft. long and 87 ft. across at the top. The depth of the turbine pit itself is 13 ft. 1 in., and it adjoins a pit 17 ft. deep for the condenser. Three machines of any of the capacities now current or planned can be erected simultaneously, the bed of the pit being designed to allow the utmost latitude in this respect, both as regards the size of the turbines and the positions of the supporting points. At each end of the pit three 10 cwt. electric hoists are mounted on 20 ft. radius swing arms, along which they can be traversed manually ; the arms are pivoted from a common vertical girder. Six 50 cwt. cranes on 18 ft. radius jibs are also provided.

The condenser was supplied by Worthington-Simpson, Ltd., to deal with 45,000 lb./hr. of exhaust steam from machines under test at 28 in. Hg. vacuum. With a surface area of 4,000 sq. ft. it is complete with its own extractor and circulating water pumps driven by G.E.C. motors.

Lubricating oil for the turbines is circulated by motor driven pumps through oil coolers, storage tanks and oil cleaning and centrifugal plant. All supply arrangements are designed to enable from one to three machines to be run simultaneously or individually at any position on the pit. Turbines are tested after assembly at overspeed conditions.

To supply steam for the new shop an International Combustion boiler of special design has been installed. This is a twin-furnace, oil-fired boiler which is differentially fired to provide steam at any pre-determined temperature up to 875° F. The capacity of the boiler is 45,000 lb./hr. at 665 lb./sq. in. gauge. Provision has been made for an independently fired boost superheater to be provided at a later stage in order to raise the temperature of the steam to 1,060° F.

Machines on Test at Opening

To mark the official opening of the new shop, Lord Citrine started up an 11,215 h.p. turbine which was on the bed for adjustment of governing valve and auxiliaries preparatory to being coupled to a 90,000 cu. ft./min. blower for a closed circuit air volume test. The complete turbo-blower is the first of two 90,000 cu. ft./min. units being supplied for the power station of the new works of Colvilles, Ltd., at Ravenscraig, Motherwell, where the G.E.C. is the main contractor for the power installation. In addition to the two turbo-blowers, the Company is supplying three 10 MW turbo-alternators and two turbo-driven water-circulating pumps for the first stage of the power station scheme. The Company's comprehensive contract for this project includes buildings,

Equipment in the machine tool annexe.

cooling towers, boilers, transformers, switchgear, lighting and all accessories.

When installed, the Colvilles blower turbines will operate at 400 lb./sq. in. gauge and 800° F., giving an output from the blower of 90,000 cu. ft./min. of air at 32 lb./sq. in. gauge. The speed will be 2,310/2,700 r.p.m. These machines are similar to the units of the 350,000 h.p. air compressor plant for which the Company recently received a unique order from the Ministry of Works.

Two turbines for G.E.C. turbo-alternator plant in course of supply to C.E.A. power stations were also on the bed. One was the sixth 60 MW machine for Uskmouth, and the other the fourth of five 30 MW, 3,000 r.p.m. turbo-alternators being supplied to the Huncoat generating station of the C.E.A.

Machine Tools

The shop is fully equipped to undertake the planing, boring and drilling of large castings and the machining of smaller parts. Rotor discs are machined in the shop, but the blades are fitted and the rotors assembled complete, and balanced, in one of the other turbine shops, whence they are delivered to the new shop for building into the machines.

Most of the machine tools are housed in the annexe, but several of the larger units are accommodated in the main shop. A Froriep 26 ft. vertical boring and turning mill installed for work on the largest parts, such as turbine exhaust casings, is one of the largest of its kind in the country. This machine was among those sent from Germany after the war as reparations. The table, made in three sections, will take a total load of 200 tons, and is 25 ft. 9 in. in diameter. A special feature is the maximum height under the tool, which is 13 ft. 11½ in.

The main motor is a 500 V D.C. machine of 173 h.p., and the speed range of the mill is from 0·2 to 6·7 r.p.m. Auxiliary motors comprise two of 7¾ h.p. for rapid traverse of the slides, and two of the same rating for rapid traverse of the rams; one 33½ h.p. motor for raising and lowering the cross rail; a 12½ h.p. motor for mechanical clamping of the rail; and a 1 h.p. oil pump motor. All auxiliary motors are 415 V A.C.

A Craven 12 ft. vertical boring and turning mill with 5 ft. 6 in. ram traverse will be installed in the main shop for machining high pressure steam casings, and arranged to admit 10 ft. 6 in. under the tool holder. The main driving motor is of 50 h.p. A 6 ft. vertical boring and turning mill of Craven manufacture is also provided and a similar machine in the annexe will be used for taper turning when machining rotor discs before the blades are fitted.

An Asquith 12 ft. 6 in. radial drilling machine in the main shop is employed on drilling bolt holes in all casings and has been adapted to take work of over 10 ft. 6 in. under the spindle.

For boring turbine cylinders, the shop is also equipped with a Noble & Lund machine taking a 12 in. boring bar. Height from the centre line to the 23 ft. 9 in. by 10 ft. work bedplate is 9 ft., and the distance between steadies 20 ft. Sixteen spindle speeds are provided by a drive from a 3 h.p. variable-speed motor through a change-speed gearbox. The main driving motor is of 20 h.p., and auxiliary 7½ h.p. motors are provided for rapid power traverse of the headstock and boring steadies, and for rapid adjustment of the outer steady.

The shop is to be equipped later this year with a 45 ft. stroke Craven planer for planing of turbine casings, with measurements of 15 ft. between uprights and 10 ft. 6 in. under the tool. This machine will have two tool boxes on the cross slide and one side tool box on each upright, and electro-magnetic tool-lifting will be incorporated to raise the tools from the work on the return stroke. Driving the table through spiral gears, the main motor will be a 120 h.p. variable speed machine supplied from a Ward-Leonard set, having a speed range of 350/700 r.p.m. Cutting and return speeds will be 20 to 120 ft./min. in high gear, and 12½ to 75 ft./min. in low gear.

Both saddles of the machine will be adapted for cross-planing and driven by a separate 25 h.p. reversing motor. The 15 h.p. motor driving the patented electric feed gear will also be used for quick traverse of the tool boxes.

Also in the main shop is a Kitchen & Wade horizontal boring and tapping machine with a 4 in. spindle, having 36 speeds and 18 rates of feed. The machine is driven by a 10 h.p. motor.

Annexe Equipment

Machine tools accommodated in the annexe comprise internal and external grinding machines, lathes, horizontal and vertical boring, facing and turning machines, and a slotting machine.

The grinding machines include a Churchill model A.C. 48 in. universal internal grinder, with 24 in. swing over the table, for grinding valve bodies; and a Churchill model C.W. 12 in. by 72 in. plain grinder for grinding governor shafts. Both machines have hydraulic table traverse.

Two Swift V5 36 in. centre lathes admit respectively 10 ft. 6 in. and 21 ft. between centres. Eighteen speeds between 4 and 230 r.p.m. are available, together with normal and coarse rates of feed. The machines have 20 h.p. driving motors. In addition, three small Swift lathes with 12½ h.p. motors and 18 speeds between 9 and 420 r.p.m. are installed for detail work.

One large Swift lathe is to be provided for cutting high-pressure turbine shafts from the solid. The length between centres will be 18 ft., and the headstock will be raised specially by 7½ in. for the work on which it is to be employed.

A Richards No. 4 Electrobore horizontal boring and

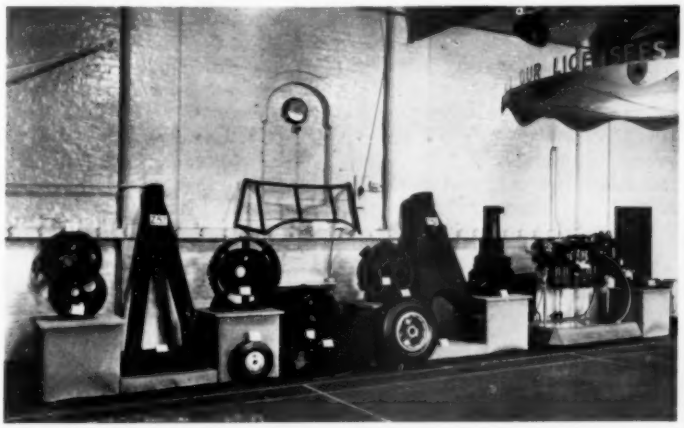
facing machine, with traversing spindle and arranged for screw cutting, is installed for work on valve bodies and small parts. Maximum height from the 4 ft. by 4 ft. revolving table to the spindle is 38½ in.

Keyways in turbine rotor discs are cut on a 16 in. Ormerod slotting machine with self-acting longitudinal, traverse and circular power feed.

A further Craven 6 ft. vertical boring and turning mill similar to the one in the main shop is installed in the annexe, together with two 10 ft. Craven machines, driven by 40 h.p. motors, of similar type.

The annexe equipment is completed by three Mitchell double-grinders, for general maintenance of tools, and an Asquith 5 ft. 9 in. portable drill.

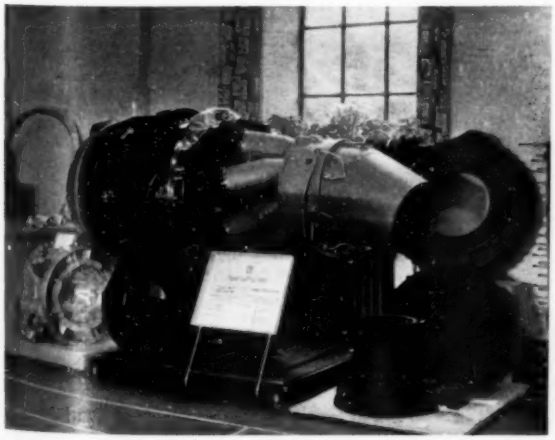
International Gathering and Exhibition Celebrate MEL's Coming-of-Age



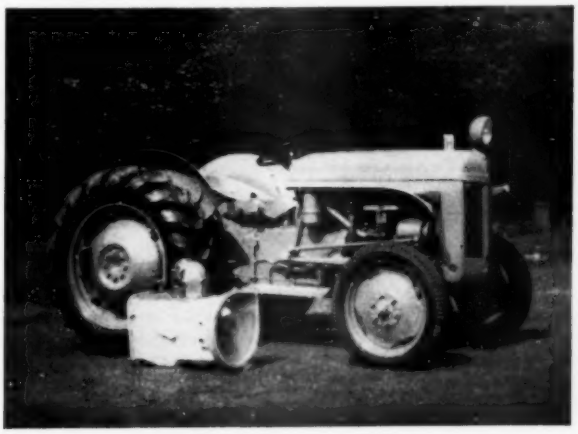
Part of the Exhibition of Elektron products

THE international gathering of licensees at the Clifton Junction works of Magnesium Elektron, Ltd., to celebrate the 21st Anniversary of the Company's establishment proved a great success. Since no comparable meeting of magnesium representatives had ever been held in this country before, the occasion was also a milestone in the history of British magnesium. Forty-seven representatives of twenty-five companies in nine countries visited Manchester, where a two-day programme had been arranged. This included the reading of four papers :* "The History of the Magnesium, Zirconium, Rare Earth, Thorium Alloys in the Foundries of the U.S.A.," by Mr. S. E. Bohn, executive vice-president, the Howard Foundry Co. ; "Quantity Production of Tractor Castings in Elektron," by Mr. W. J. Sully, director and general manager, Sterling Metals Ltd. ; "The Work of the Metallurgical Research Department of Magnesium Elektron, Ltd." by Dr. E. F. Emley, chief metallurgist, Magnesium Elektron, Ltd. ; "Modern Concepts in the Protection of Magnesium Alloys," by Dr. W. F. Higgins, senior metallurgist, Magnesium Elektron, Ltd. ; and the showing of a film, specially compiled for the occasion, illustrating "The Development and Application of Wrought Magnesium Products in the U.S.A." This was presented with a commentary by Dr. J. D. Hanawalt, vice-president and manager of the Magnesium Department, the Dow Chemical Co. In addition, extensive tours of the works, in small parties,

* Two of these papers are published in this issue and the remaining two will appear next month.



The Rolls Royce "Dart" turbo-prop engine, which embodies 82 ZRE1 castings.



Fordson tractor with transmission case and lower housing cast in magnesium alloy.

had been arranged for all visitors, and ample time was also provided for private discussions with the company's technicians. An exhibition—the first of its kind to be held in this country—in which all the English licensees were represented with some of their best and most interesting work, gave overseas visitors a good idea of the standard of magnesium craftsmanship here.

Naturally the main accent lay with the magnesium-zirconium alloys, which now represent over 57% of M.E.L.'s production for aircraft usage. Amongst the components shown were a complete Dowty main undercarriage in Z5Z, with Z5Z wheels by Dunlop, for the Avro "Vulcan"; the RZ5 crankcase of the Napier "Nomad"; several large ZRE1 castings (air intakes, etc.) from famous aero engines; the RZ5 canopy of the D.H. "Sea Venom"; a "G" type E.R.A. car chassis frame in welded Z.W.1. alloy tube; examples of extrusions, forgings and sheet (including a printing plate made from "Primag" magnesium alloy); and a selection of textile machinery accessories fabricated by M.E.L. themselves. Two celebrated engines, the "Dart" and the "Gipsy Queen 70" were also on view. In the "Dart" (which powers the "Viscount") there are 82 ZRE1 castings totalling a fettled weight of 364 lb.

The visitors also welcomed the numerous opportunities afforded for getting to know their opposite numbers in this and other countries and for discussing with them mutual problems. The social side of the proceedings reached its climax at a dinner held in the Midland Hotel, at which 82 persons were present and at which Major C. J. P. Ball, D.S.O., M.C., F.R.Ae.S., chairman of the company, presided. As is well known, Major Ball has been the moving spirit behind the British magnesium industry since 1923.

Speakers at the dinner referred in a jocular vein to the difficulties, misgivings, and misunderstandings which had attended the early days of magnesium in this country. As to the future, the respresentative nature of the meeting itself afforded the best possible evidence that it can be viewed with optimism.

Iron and Steel Import Duties Further Suspended

After consultation with the Iron and Steel Board about the supply position, Her Majesty's Government have decided to make a new Order affecting the temporary suspension of import duties on iron and steel. The Order prolongs the temporary suspension of import duty on cold rolled steel sheet of a value of less than £80 per ton until September 18th, 1956; and suspends until March 18th, 1956 the import duties on a wide range of iron and steel products. The duty on most of these, including tinplate and tinned sheets, is already suspended until September 18th, 1955.

In order to ensure adequate supplies of ferro-manganese for the manufacture of steel in the United Kingdom, the Government have also decided to suspend the duty on blast furnace ferro-manganese until March 18th, 1956.

So as to ensure that imports of tinplate do not displace the output of the hand mills, the Government have obtained a renewed undertaking from the producers and the main consumers of tinplate that all available home-produced tinplate, including the full output of the hand mills, will be taken up.

The new Order, which is known as the Import Duties (Exemptions) (No. 7) Order, 1955 (S.I. 1031) came into operation on July 22nd, 1955. It replaces the Import Duties (Exemptions) (No. 1) Order, 1955 and continues the duty suspension introduced by the Import Duties (Exemptions) (No. 8) Order, 1954. Copies of the new Order may be obtained from H.M. Stationery Office or from any bookseller, price 3d. (by post 4½d.).

Iron and Steel Prices

The Iron and Steel Board has announced increases in maximum prices, effective from the 25th July, over the whole range of iron and steel products in respect of which these are determined by the Board. The cost of production has been affected in various items, notably the higher price of coal; the increase in the landed cost of imported materials; the increase in railway rates announced in May; and the general wages increases which have recently been negotiated within the industry.

The Iron and Steel Board considers that the margins for depreciation, obsolescence and profit determined by them at the end of last year, following their comprehensive review of the price structure, are those necessary for the maintenance of a healthy and expanding industry. Although as a result of increased production and efficiency it is possible for the industry to absorb some part of the increases in cost, the greater part must now be reflected in the prices of iron and steel products if the foregoing objective is to be maintained.

On average, the increases in iron and steel prices represent approximately 5% on the price of finished steel products. But the incidence of the increased costs is unequal, and generally speaking the price adjustments are proportionately greater in relation to prices of the less highly processed material than in the case of more highly finished products. The range of price increases is indicated below :—

Class of Product	Percentage Price Increase
Basic pig iron	7%
Foundry pig iron	9½%
Semi-finished steel	6½%
Heavy steel products (plates, joists, sections, rails)	5¾%
Hot re-rolled products	5½%
Sheets—	
Strip Mills	4½%
Hand Mills	6½%
Tinplate—	
Strip Mills	2¾%
Hand Mills	5½%
Hot finished tubes	5½%

The new prices will be approximately 15% below American and Continental prices.

EFCO's New South African Subsidiary

EFCO, Ltd., announces the formation of a subsidiary company in South Africa, in collaboration with its South African agents, D. Drury & Co., Ltd. The new company is named EFCO (South Africa) (Proprietary), Ltd., and has an authorised capital of £S.A.50,000. The board will consist of J. A. Monks and J. C. Howard, who are also directors of EFCO, Ltd., and as South African members, A. D. Hodgson, R. P. Hacking and H. G. Goyns. The registered office is in Johannesburg. The company will supply all types of electric furnace equipment for melting and heat treatment of metals.

The History of the Magnesium, Zirconium, Rare Earth, Thorium Alloys in the Foundries of The United States *

By Stewart A. Bohn

Executive Vice-President, Howard Foundry Company

The magnesium, zirconium, rare earth, thorium alloys owe their introduction to the United States to the acquisition by Pratt and Whitney of the rights to manufacture the Rolls Royce Tay jet engine, which embodied several high temperature magnesium applications. When initial difficulties due to prejudice and foundry problems had been overcome, progress was fairly rapid, and the author's foundry may this year cast a million pounds of these materials.

HOWARD FOUNDRY COMPANY was the first United States sand casting foundry to produce the rare earth magnesium alloys developed by Magnesium Elektron. We started production in April of 1949, in which year we needed only two 300-lb. gas-fired furnaces to melt the rare earth alloys. By the end of 1950 we were using six 300-lb. furnaces, and at the close of 1951 we were building a special furnace room. This room now consists of four 2,000-lb. tilting furnaces, twelve 500-lb. furnaces and twelve with 300-lb. capacity.

At the present time, 50% of Howard Foundry Company's production consists of the rare earth alloys. At the existing production rate it is quite possible we shall pour 1,000,000 lb. of rare earth alloys in 1955. However, this anticipated production is based on the Government's enlarged Defence Programme, which has been indicated recently.

This 1,000,000 lb. potential actually represents a rather dramatic growth, for six years ago we were pleased to have poured some 2,000 lb. of rare earth alloys in a nine-month period. A fuller appreciation of the strides made in America can be gained from the fact that the United States magnesium foundry industry shipped, or sold, 2,750,375 lb. of rare earth alloys in the past five years.

Introduction of the Alloys

These figures, I believe, indicate the progress in the United States, but they don't tell the story behind that progress. In the beginning we got into the production of rare earth alloys rather fast, and it wasn't, as you might think, because of our American habit of racing the clock. We were simply pressed into action by a combination of events. First, an American aircraft engine manufacturer, Pratt & Whitney Aircraft Division of United Aircraft, had acquired rights to manufacture the Rolls Royce jet engine, known as the Tay. Second, the Rolls Royce jet engine embodied several high temperature magnesium applications, one being the compressor cases, which were subjected to temperatures ranging far above the safety limit of magnesium alloys then in use in the United States.

These were the circumstances that brought us to England's shores. The United States foundry industry had to get the license to manufacture the British rare earth alloys so that Pratt & Whitney Aircraft could manufacture the Tay jet engine, using the magnesium alloy specifications of Rolls Royce designers.

Frankly, outside of Pratt & Whitney Aircraft, United States aircraft engine manufacturers felt reluctant about using the British alloys, regardless of the stated advantages. They were concerned about placing dependence in a materials source outside the country. If an emergency suddenly arose, they reasoned, what would happen to supply? What is more, Howard Foundry Company was the only supplier of the rare earth alloys in the United States. That made the use of these alloys less attractive still. For no defence manufacturer in our country wishes to rely solely on one source. The reasons for this, I believe, are obvious. Naturally, Howard Foundry Company was very much interested in another United States foundry source being established. Once it was, our task of promoting acceptance of the rare earth alloys was eased considerably.

We still encounter some reaction to the overseas materials source, by the way, although it is a point we often overcome by simply referring to the excellent and confident experience of our defence customers. Today, of course, you will find that the first rare earth alloys introduced to the United States have military specifications included for all our armed services. These alloys are known as ZRE1 and Z5Z.

Creep Testing Differences

On the introduction of the rare earth alloys in the United States we ran into a particularly vexing problem. It involved the British system of measuring stress loads by using the 1,000-hour creep test. In the United States design engineers are accustomed to working to a 100-hour creep test with specified elongation. The practice in our country is to design to higher stress loads for shorter periods of time. When the British figures were introduced, they meant nothing to our engineers: there simply was no accurate way to extrapolate.

United States design engineers wouldn't stop to figure out what was the difference between the creep curves of the British and United States alloys. They would simply assume one was better than the other. It is understood that some 1,000-hour creep tests have been run in the United States, but I doubt very much if this longer test

* Presented at the international meeting of licensees of Magnesium Elektron, Ltd., held on June 16th–17th, 1955, to mark the coming-of-age of the company.

will ever become standard or even supplemental practice in our country. It just takes too long for our engineers to get the required information.

As you might expect, we also encountered varied opinions as to reliability of the British testing method and the United States method. When we approached American design engineers, they questioned the British system. When we approached the British about changing their system for us, they kindly suggested we change our system for them. We, in the foundry industry, didn't wish to provoke an international engineering incident, so we adjusted ourselves to both systems. I might add, of course, that any question of reliability of one system as opposed to the other is purely a point of view affected by an application. So, it is impossible to win an argument on this point.

Although the difference in approach to testing certainly posed a big problem, and still does in some cases, it was not the basic hurdle. " Proof of the pudding is in the eating," as the saying goes, and United States design engineers require more proof than facts revealed by assimilated tests, particularly when those facts may be arrived at in an unfamiliar manner.

That means we had to gain some experience with the rare earth alloys, which, exclusive of the Rolls Royce jet engine project, was very much like the young man who, in seeking his first job, finds employers telling him to get experience, then come back to see them. Fortunately, the entree for the rare earth alloys was the Rolls Royce Tay engine. For this engine created the need, even though assimilated tests of the rare earth alloys were the only evidence of performance available.

The importance of gaining experience with a new alloy in the United States cannot be stressed too strongly. Lack of service experience is holding up wider use of the thorium alloy today, for example. And it is entirely possible that by the time we get the service experience, the evolution of jet engine design will have obsoleted the thorium alloy.

If we had had United States service proof of the capabilities of the rare earth alloys back in 1949, far more rare earth alloys would have been used in the past six years. Today, of course, these alloys are not being specified for use in many new jet engine high temperature applications, for jet engine operating temperatures are rising, and to such a point that even high temperature aluminium is passing out of the picture. Titanium doesn't seem to be the answer, as was hopefully expected, and, reluctant as the jet engine manufacturers may be, they are being forced to turn to high alloy steels. At the moment, these heavy alloys would seem to be the only solution.

Selling the rare earth alloys was one thing ; producing them was something else again. We were completely in the dark as to their casting characteristics. And since we were interested in gaining foundry experience as quickly as possible in 1949, we put Magnesium Elektron engineers to work in our foundry. I dare say they recall their experience in an American magnesium sand foundry with mixed emotions.

Unlike foundry licensees of Magnesium Elektron on the Continent and in England, we couldn't afford to buy alloyed ingot from M.E.L. Import duty on the ingot is 20c./lb., and, if alloyed, there is an added 10% *ad valorem* duty, or a tax on the actual value of the alloyed ingot. If we had to absorb or pass along these import costs, the United States Air Force might just as well be flying kites as far as rare earth magnesium alloys are concerned. So, we started alloying our own magnesium, buying the primary magnesium, mischmetal and zinc locally and getting the Master Salt and HE Flux from Magnesium Elektron. This practice is followed today.

Foundry Practice

We don't transfer our metal with electric cranes, which are used in England's magnesium foundries : we use monorail. Admittedly, the electric crane is smoother, and the British engineers, who were helping us, found our monorail system somewhat antiquated and difficult to get accustomed to. We couldn't, of course, suddenly convert to electric cranes, for that would have necessitated rebuilding our foundry. Fortunately, we've found we obtain comparable results with the monorail system.

It is our practice to melt and alloy rare earth magnesium alloys in 2,000-lb., gas-fired tilting furnaces, as mentioned earlier, and to achieve correct analysis with the help of the Quantometer. We then transfer the melt to 300-lb. or 500-lb. holding crucibles. Revivification is performed by the prescribed M.E.L. method, with the exception of puddling.

Puddling posed a momentary problem initially, and our British foundry friends were somewhat concerned. They use a hand puddling method, whereas we started using an air-driven mixer. Once, when we ran into some trouble in our earliest experiments with casting the rare earth alloys, our British friends eyed the mechanical mixer sceptically, and that was enough for us. We stopped puddling with the mixer, while our British foundrymen showed us the puddling method used in England. They were kind enough to do this personally, and the heat was so great that within the hour we were back to using the mechanical mixer and searching for our trouble in another place.

Another area where foundry practice differs is in our use of screens, or metallic skim gates. British magnesium foundries don't use them. They use a double-runner system to keep the mould metal clean. We've tried eliminating screens with no success, which, obviously, is due to the fact we do not use the double-runner system.

We also use a harder sand core than the British, who use green sand cores that are the envy of our foundrymen. We would like to use them, and have tried, but we have found that special handling procedures have to be established, interfering with our normal foundry production. That's the reason for our use of the harder cores—we simply don't handle cores as carefully as the British. The harder cores, by the way, seem to have an adverse effect on Z5Z, developing hot shortness in this alloy, which seems subject to this condition. We do not cast much Z5Z for this reason.

A great deal of the British quality evaluation is based on fracturing. We admit a lot of information is obtained this way, and we do a lot of it, but our customers in the United States do not like it : they prefer X-rays, which can be used to give permanent records. So, instead of destructive testing periodically, we X-ray all castings, and the customer can use all castings that prove acceptable.

In the United States, we have to do more fettling. Our customers require a finely finished casting, which requires us to do more finishing. British and European

buyers, it would seem, are more realistic about finish, accepting good castings without the requirement of eye-appeal.

Learning new techniques, adjusting ourselves to the characteristics of casting new materials, is a foundryman's job. As is the case so often in the magnesium foundry industry, no rule book existed for us in successfully casting the rare earth alloys. British engineers were of great help, but we still had to establish procedures relating to our own production habits. For it is more by habit than by choice that we are accustomed to treating virtually every magnesium casting project as a new project with a new set of problems. Trial and error is often the most scientific method of successful production, simply because of the rigid, often quite unusual, demands placed upon our industry. This was Howard Foundry Company's experience before the inception of the rare earth alloys, and this was the experience that helped us pioneer the rare earth alloys in the United States.

Future Prospects

There, briefly, is the history of the rare earth magnesium alloys in the United States. But—and if I may be permitted to deviate for a moment—what is the future of these alloys in our country ?

As you may have gathered already, most, if not all, rare earth alloys go into defence applications in the United States. Before leaving for England, we checked with various magnesium sand foundries to determine if any of their production was channeled into what we call the commercial market, or the non-defence market. They reported no commercial use of the alloys and didn't anticipate any.

The largest volume of rare earth alloy production goes into compressor housings for axial flow jet engines. But this may be considered the first use of rare earth alloys in the United States, so it would appear we have progressed little in promoting acceptance of these alloys. Actually, the reverse is true, for these alloys are well-recognized by aircraft manufacturers, for whom the alloys were developed.

At first they were sold on the basis of their high temperature characteristics. More recently they've been sold on their " as cast " pressure-tight characteristics. I cannot speak for the entire magnesium foundry industry at home, but I do know we at Howard Foundry Company are casting many more applications where temperature is no consideration. These applications, most of which are auxiliary aircraft parts, must be pressure tight. The fact that the British alloys require no impregnation for pressure tightness has become an important factor in their present-day use. And, of course, because of the excellent weldability of ZRE1, it is being used in many applications that must be joined. However, outside of these fairly recent developments, which hold some promise, the market picture is not entirely pleasing to our eyes.

I mentioned earlier that rare earth magnesium alloys are not being specified for many high temperature applications in the newer jet engines, because temperatures have risen beyond the safety limits of these alloys. This gives us pause for thought : and speaking for the magnesium sand foundry industry in the United States, the thought is about the development of a new magnesium alloy that could meet the new and higher temperature requirements. Such a development may be considered impossible with today's metallurgical knowledge, but there have been many " impossible " tasks solved by studied intent and plodding purpose.

Need for Educational Publicity

Although no commercial market exists for rare earth alloys, due to their high cost, even the standard magnesium alloys face the same marketing problem in the United States, particularly as the metal involves sand casting. That, perhaps, may strike many of our British and European friends as odd, since the United States is not only known for its mass production abilities, but also for its merchandising abilities, or its ability to create demand for the materials and goods produced. The Germans, with their Volkswagen Works, use a surprising amount of magnesium in their automobiles, while the British use good sized quantities in tractors and and other applications. Of course, this is mainly secondary metal they are using, but even secondary magnesium plays little part in the commercial casting market in the United States.

In our country we have a plentiful supply of good iron. Furthermore, aluminium, although tight in our market right now, is consumed in large quantities and sells for about nine to ten cents a pound less than magnesium. The word aluminium in the United States is virtually a household word ; magnesium is not. As a matter of fact, the Chairman of the Board of Howard Foundry Company, Frank C. Howard, Sen., in a talk delivered to the Ninth Annual Meeting of The Magnesium Association in New York City in 1953, pointed out that one of the magnesium industry's problems in our country was the lack of general knowledge about magnesium. It was Mr. Howard's opinion that the public could not identify the word magnesium. To find out if he was right, he commissioned a market research organization to conduct a small survey.

The survey consisted of asking people two questions : interviews were made by phone. First, they were asked : " What is magnesium ? " If the answer was a metal or an alloy, the individual being questioned would then be asked " What do you know about magnesium—what are its characteristics ? " The number of people interviewed was 516. Slightly more women than men were questioned. Interviews were held as much as possible to the middle income groups, but most economic groups were represented. Most people interviewed were in the 20 to 49 age groups.

Some 78% of the people interviewed—or 402 of the 516 persons questioned—had no recollection of ever hearing the word before. These figures included 60% of the men and 85% of the women. Quite a few people simply tried guessing. Some of them said magnesium was a laxative. Others said it was a chemical or mineral or liquid. Still more said they couldn't quite remember. As Mr. Howard himself stated : " One nice lady thought you and I were in the cosmetic business. Another wasn't sure, but she thought we were playing around with a rare vegetable—" and then Mr. Howard said "—*rare indeed* ! "

Only 28 men answered that magnesium was a metal and that its characteristic was an alloy. Some of these gentlemen not only identified magnesium as an alloy but also identified its characteristic as an alloy. Magnesium and light weight were associated by only 23 men and 8 women. Some people who identified magnesium

as a metal or an alloy evidently were somewhat confused about what was meant by characteristic. For example, some said that the metal's characteristic was its use in manufacturing appliances. Others thought its characteristic was its use in medicine, thermodynamics, radio receivers and television parts. Magnesium's machining qualities were mentioned once—by a woman. She said magnesium was hard to machine!

Problems in Using Magnesium

To improve the commercial marketing position of magnesium, it was Mr. Howard's thought to enlist the aid of public knowledge about magnesium. But to do this requires an educational programme on a broad and consistent plane. Aluminium's successful growth can be traced in no small measure to educating the public to the advantages of the metal, which, in turn, conditions manufacturers and their designers to its benefits. Magnesium does not have the overall acceptance we would like to see, and, as a result, the promotion of the rare earth alloys is somewhat affected.

Naturally, competitive metals and magnesium's price affect the entrance of magnesium into more commercial fields. But quite often, when price doesn't enter the picture at all in a new application, certain of magnesium's characteristics hurt its sale. This happens with all materials, but we feel it most because we are acutely aware of the need for new markets for magnesium.

Galvanic corrosion is one problem we face. Because of it, there is a tendency on the part of many design engineers to think magnesium will corrode in normal atmosphere. Actually, magnesium is being used successfully in many applications subject to atmospheric conditions. Again, magnesium won't take a polish readily, a fact that has forced some manufacturers to abandon plans for using magnesium cast component parts in commercial products.

These problems, however, are often quite minor in comparison to human nature. For all too often we encounter people who want what no one has, and failing to obtain it, ignore what we can offer. This is especially true when rare earth alloys are considered. The classic example is the request for a magnesium alloy that won't corrode, that will cast like ZRE1, that will have the properties of TZ6 and will sell for the price of "C" metal. To be sure, United States defence manufacturers are interested in alloy improvement and advancement, and we look hopefully to our British metallurgists for more major magnesium alloy contributions.

For, even today, Magnesium Elektron's rare earth magnesium alloys are edging out the use of aluminium alloys in some cases. And, back in 1949, were it not for these alloys, most, if not all, jet engine high temperature applications would have gone by default to aluminium. So the United States magnesium foundry industry is justifiably proud of its association with Magnesium Elektron, which protected and helped maintain markets for our industry's services and facilities. Although the future of the rare earth alloys may not appear to be bright in every market area in our country, it is a future we can cope with, I believe.

New fields are being opened, although slowly perhaps. Nevertheless, each step into a new area by the individual rare earth magnesium-producing foundries in the United States tends to help all of us as an industry. In effect, we are maintaining our position as a thriving industry while giving time for metallurgical research to develop alloys that will mean secure progress. Even without new metallurgical developments, however, we are confident the rare earth alloys produced by Magnesium Elektron are in our country to stay, to help us prosper in the foundry industry.

Titanium Project in the United States

IMPERIAL CHEMICAL INDUSTRIES, LTD., and Columbia-Southern Chemical Corporation, of Pittsburgh, U.S.A., have submitted a joint application to the United States Government for a contract under which the Government would undertake for a 5-year period to purchase 5,000 short tons per annum of granular titanium metal. In their application the companies have stated that they have completed arrangements for the introduction into the United States of a granular titanium process not at present employed there, and would also make available to fabricators techniques not at present known or employed in the United States.

If a contract is awarded, I.C.I. and Columbia-Southern Chemical Corporation will form a jointly-owned subsidiary for the purpose of producing granular titanium metal by I.C.I.'s sodium reduction process. The parent companies will each hold a 50% interest in the new company, which would be known as Columbia Titanium Company. The plant would be built at Natrium, West Virginia, and would have a capacity of 5,000 short tons per annum. The cost of the proposed granular titanium metal plant will be in the region of 10 million dollars.

I.C.I.'s patent position and production experience have an unusually broad base, through their experience of chemical and metallurgical technology, and extend from the production of granular titanium metal by their new sodium process, to melting, scrap recovery, alloying, testing, jointing and fabrication, in the latter of which, particularly, they are favourably placed by virtue of their wide experience in non-ferrous metal technology.

Columbia-Southern's contribution to the proposed joint enterprise lies in the production of titanium tetrachloride, from which granular titanium metal will be made. Columbia-Southern, which is itself one of the leading American producers of chemical products and is a wholly-owned subsidiary of the Pittsburgh Plate Glass Company, has been engaged in research on the chlorination of titanium-bearing ores since 1937. It has established a broad patent position in this field and today licenses other companies under Columbia-Southern patents.

Columbia-Southern and I.C.I. believe that their proposal to the Government will result in lower capital and production costs and in the acceleration of a titanium fabrication industry in the U.S.A.

Imported Wire Goods

THE Board of Trade have been advised that imported wire goods should bear an indication of origin at the time of importation and when offered for sale. This recommendation is contained in the report of the Standing Committee set up under the Merchandise Marks Act, 1926, and published recently as Command No. 9528, Price 4d. (post free 5½d.).

The Work of the Metallurgical Research Department of Magnesium Elektron Ltd.

By E. F. Emley, Ph.D., F.R.I.C. F.I.M.
Chief Metallurgist

In addition to the technical liaison work between the company and its licensees, and to patent work in connection with the company's world wide interests, the Metallurgical Research Department of Magnesium Elektron, Ltd., is actively engaged in the development of new and better alloys, including alloys for specialised purposes, with a view to extending the industrial applications of magnesium. It is to the latter aspects that the author draws attention in this paper.

THE principal objectives of metallurgical research in the works of Magnesium Elektron, Ltd., are: (*a*) to develop new and better alloys, including alloys for specialised purposes, and so to extend the usage of magnesium; and (*b*) to give technical assistance to customers. The Company has for many years placed particular importance on research and development, and has not hesitated to provide the necessary facilities. The laboratories are particularly well equipped for an organisation of its size.

Under Dr. F. A. Fox, who was Chief Metallurgist from 1938 until the end of 1946, the department was built up substantially to its present size, and many alloy systems were investigated, including the Mg-Zr system. The metallurgical team led by the late Capt. A. C. Jessup, and supported by the work of the chemical team led by Dr. A. L. Hock, successfully developed the now well-known Mg-Zn-Zr and Mg-Zn-RE-Zr casting alloys typified by Z5Z and ZRE1, respectively. In this work they were greatly helped by the initiative of the licensees, and in particular by J. Stone and Co., Ltd., and Sterling Metals, Ltd. In the wrought field the alloys ZW3 and ZW1 were developed, but the extruded forms have not as yet achieved the widespread use in this country which the similar alloy ZK60 (ZW6) has enjoyed in the U.S.A. More recently, also under Capt. Jessup's inspired leadership, the thorium-containing casting alloys ZT1 and TZ6 were successfully developed.

The steady increase in the number of the Company's licensees has naturally meant an increasing amount of technical liaison work for the Metallurgical Research Department, fortunately kept within practicable limits by the high quality of the work done by the licensees themselves (for example, one licensee advised us last year that they had made over 600 consecutive zirconium alloy melts without one falling below specification on tensile properties). Similarly, the world-wide nature of the Company's activities involves the department in a great deal of patent work. In the notes which follow, these activities of the department will be taken for granted, and attention directed mainly to various fields in which research and development work are now being conducted. Mention is made of a number of lines on which the Company is working, and some of its thoughts for the future. It will be appreciated, however, that in many such cases little further information can be given at the present time.

* Paper presented at the international meeting of licensees of Magnesium Elektron, Ltd., held on June 16th–17th, 1955, to mark the coming-of-age of the Company.

Organisation of the Department

The department is organised broadly into sections specialising in research and development in the cast and wrought alloy fields; melting, alloying and purification; sand casting and technical service; corrosion and protection; and service sections dealing with mechanical testing, radiography and X-ray diffraction, and control and inspection. The lines of demarcation are not too sharp, and use is made of "shock-troop" tactics to break open a problem, which may then be left to the appropriate section to perfect a solution. Close liaison is maintained with the Foundries Department by frequent informal meetings. A valuable feature of this co-operation is the ability of those engaged on research work to supervise the trial of their ideas on a production scale. Without the active help of the Foundries Department, many ideas originating in the Research Department would never come to practical fruition. Very close relations have always been maintained with the Chemical Research Department, who not only carry out the many and varied analyses required in the metallurgical research work, but also contribute in many ways to the success of the work itself. The Chemical Research Department's own activities are very wide, and even include the production of high purity vanadium. Their work has naturally led to the erection of very extensive plant for the production of zirconium compounds.

Survey of Recent or Current Work

In the following brief survey, some recent and current work is reviewed:

Cast Alloy Development

Since the development of the thorium-containing alloys ZT1 and TZ6, work has continued on the possibility of improving these alloys further. In the field of high temperature alloys, the effects of various small additions to ZT1 have been tried without materially improving creep resistance. Means have been sought for improving the corrosion resistance of this alloy after ageing at temperature, and it has been found that a small addition of indium gives a marked improvement. Based on an unexpected discovery, a modified alloy system containing thorium is under investigation which has yielded an alloy capable of withstanding considerably greater stress at 350° C. for 0·5% strain in 1,000 hours than can ZT1. This alloy possesses quite good corrosion resistance without recourse to an indium addition. It

has, however, some " snags " which it is hoped are now in the process of being eliminated.

In carrying out creep tests on ZT1 alloy at high temperature and stress, it was noticed that a few bars showed superficial oxidation accompanied by some reduction in resistance to creep. The alloy was not, however, embrittled. An investigation of this phenomenon has shown that it only occurs under stress and in the presence of specific surface contamination. If the surface is contaminated with iron, such as results from cleaning by shotblasting, some oxidation may occur; the extent of this is much increased if chloride is also present, arising, for example, from marine spray, or even contact with human perspiration. However, if shotblasting of ZT1 castings is avoided, no trouble need be anticipated in practice from this cause. They may safely be cleaned by shotblasting if treated subsequently by the M.E.L. fluoride anodising process. Tests on some other cleaning processes are in progress.

Creep tests at 250° C. have shown the marked superiority of ZT1 over ZRE1, even at this relatively low temperature. Thus ZT1 will withstand about 3½ tons/sq. in. for 0·5% total plastic strain in 1,000 hours compared with about 1½ tons/sq. in. for ZRE1.

It is encouraging to note the increasing use of ZT1, particularly in the U.S.A. A recent paper by K. E. Nelson, of the Dow Chemical Company, shows clearly how well the tensile and creep properties of specimens cut from actual castings duplicate those from standard test bars. A good deal of interest has also been shown in TZ6, but so far it has found no extensive use. The advantages of this alloy in giving improved tensile properties and increased soundness in comparison with Z5Z, whilst being fully weldable, should surely result in increasing application. One can even get a further 1½ tons/sq. in. out of TZ6, as regards both 0·1% proof stress and ultimate tensile stress, by substituting for the standard heat treatment a prolonged treatment at 100° C.

In this same class of material, another alloy system is under investigation which does not involve thorium, and which can give much the same high tensile properties as TZ6. A particular advantage is a 0·1% proof stress of 11 tons/sq. in. in 3 in. sections. Here again, some potential " snags " await solution before it is possible to say whether or not this alloy will be of practical use.

Wrought Alloy Development

Work is in progress on the development of wrought high temperature alloys. Although the alloy ZT1 will withstand considerable stresses at elevated temperature, it is not as resistant to creep in the wrought as in the cast state. However, other alloys with lower thorium content are being developed which will give better high temperature properties at lower cost.

A wrought alloy is under development which it is hoped will show reduced directionality in tensile properties.

The properties of TZ6 alloy in wrought forms are being investigated to see whether the advantages in tensile properties over ZW3 look sufficiently marked to justify the extra cost.

One potential disadvantage of magnesium-zirconium base wrought alloys has been the presence of some clusters of zirconium-rich particles in cast billet and slab which, on working, can become drawn out into stringers, and which may conceivably affect fatigue properties. Their presence appears to affect forging. Early work on the fatigue properties of ZW3 sheet and plate showed that the resistance of plate to fatigue appeared considerably lower than that of sheet. At present it is not known for certain whether this phenomenon is connected with particle stringers or with specimen size or thickness and it is not known how the alloy AZ31, on which good service experience is available, behaves in this respect. Accordingly, an elaborate series of push-pull fatigue tests is in progress on AZ31 and ZW3, in which the relative effects of specimen size and specimen thickness are being determined. The programme includes the testing of ZW3 particularly rich in zirconium particles.

We are also investigating a modified Wöhler fatigue test involving a special test bar shaped to give a constant stress over the whole of the gauge length. This should ensure that failure occurs at any weak points rather than in the position of maximum stress, which is normally the case.

So far as extrusion is concerned, it appears probable that the presence of particles is not seriously deleterious to wrought zirconium alloys, and the success of the alloy ZK60 in U.S.A. bears out this point. Scrap ZK60 extrusions taken from service in U.S. aircraft have in fact been examined at Clifton Junction and found to contain heavy local stringers of zirconium-rich particles.

For some time we have been working on methods of eliminating these particles from wrought zirconium alloys—with a considerable degree of success. Further development work in collaboration with the Foundries Department is, however, needed before the process can be applied to all production billets. The procedure used is also effective in eliminating manganese particle clusters from AZM billets, and represents an extension of earlier work which had substantially reduced the presence of insoluble particles in AZM billets for forging.

In addition to work on the effects of particles on the fatigue of wrought alloys, the effects of various surface treatments on rotating bending fatigue life are being closely studied. In particular, it has been found that, whereas chemical dip treatments normally reduce the fatigue resistance of extruded ZW3 alloy, and the very hard H.A.E. film causes a marked reduction in fatigue life, the effect of the M.E.L. fluoride anodising process appears beneficial.

Experiments in various atmospheres and with rubber coatings have shown that, in the absence of either oxygen or moisture, extruded ZW3 gives a typically ferrous S/N curve with a true fatigue limit. This indicates that failure, under normal conditions of testing, is really attributable to corrosion fatigue. As regards corrosion fatigue itself, accelerated tests are in progress to compare the susceptibility of extruded ZW3 and AZM to this phenomenon. The latter alloy is proving slightly more susceptible.

An exploration of the possibilities of scratch-brushed magnesium powder for compacting by extrusion is in progress. Interesting room temperature properties have been obtained, but whilst the extrusions are remarkably resistant to annealing, the high temperature properties are relatively disappointing, and in no way comparable with those of extruded " S.A.P."

Melting, Alloying and Purification

Much experimental work has been involved in the development of the best methods of preparing thorium hardener alloy, and in acquiring an understanding of the various difficulties which can arise. Because of the

high cost of the metal, methods have had to be worked out by the Chemical Research Department for recovering thorium from residues arising at all stages of the process.

A metallic zirconium alloying agent specially suitable for use with thorium alloys has been developed with a view to keeping thorium losses in processing to the lowest possible level. It is hoped this product may shortly be available, at least in experimental quantities.

The old manganese alloying process using $MnCl_2$ has recently been modified with marked improvements in manganese alloying efficiency and in metal recovery and consequent reduction in the production cost of the Mg-Mn binary alloy.

Progress has been made in the preparation of high purity A8 and AZG anode alloy, and improved methods worked out for achieving better iron separation with increased metal recovery. The Company has for some time been working on the improvement of the corrosion resistance of high purity A8, and has now prepared 6 tons of experimental alloy possessing a corrosion rate, judged by the standard immersion test, of between one-fifth and one-tenth that of the normal high purity alloy ingot supplied to D.T.D. Specification 684.

A new carbon grain refining agent which is more effective and cheaper than hexachlorbenzene or hexachlorethane has been developed and is freely available.

Sand Foundry Development Work

Investigations have been carried out on the efficiency of different running methods, as judged by the soundness and fatigue resistance of the resulting cast metal. For this purpose an open box casting with vertical walls of different thicknesses was chosen, so as to facilitate examination by radiography and by cutting test specimens from the casting.

The best results have been obtained with an " upsprue slitgate " system, the slit being applied to, and itself thicker than, the thickest wall of the casting, and a riser being placed over the thick wall in the neighbourhood of the slit. Using such a running system, complete soundness was obtained in $\frac{1}{2}$ in. walls with A8, and with Z5Z only traces of residual "ribbon" porosity remained. The Wöhler fatigue results on small bars cut from the $\frac{1}{2}$ in. Z5Z walls were excellent ($\pm$ 5·5–6·0 tons/sq. in.) and very slightly better than with A8. With 1 in. walls and the same running system, neither alloy was completely sound and the fatigue results with Z5Z varied from 4 to 5 tons/sq. in. Using bottom pouring : the scatter in tensile properties in bars cut from the castings was much greater in the case of A8 than in Z5Z.

Starting with the " upsprue slitgate " running system, under conditions giving complete freedom from microporosity, we have investigated separately the effects of adding hydrogen and underfeeding (by omitting the riser), and have confirmed that the types of porosity produced are radiographically indistinguishable.

The " upsprue slitgate " system has been applied successfully to a number of production castings.

A survey of the hydrogen content of various alloys is being made with a view to understanding more clearly what part hydrogen plays in magnesium technology. In order to deal with the analyses a vacuum fusion apparatus is installed in the Chemical Research Department.

Corrosion and Protection

The main work in this field has been the development of the fluoride anodising process and of surface sealing with epoxy resins. These form the subject of a separate paper.*

Service Sections

The Mechanical Testing Section is responsible for all tests for routine control and inspection purposes, carries out determinations on experimental alloys, and collects data on existing alloys. Much of its work is now devoted to high temperature fatigue and creep testing, and for this purpose a new, large, air conditioned laboratory is being built which will house, in addition to a Quantometer, a 6-ton Losenhausen push-pull fatigue machine, and additional creep testing equipment. Mention was made earlier of the fatigue investigations in progress and, in this connection, a selection of magnesium alloys, both wrought and cast and representing a wide range of fatigue strength, have been supplied to a Research Association for testing by a recently developed rapid fatigue testing method. Incidentally, electron micrographs are being taken by a Research Association of specimens supplied by the Metallurgical Department with special reference to possible correlation between fine structure and resistance to corrosion and to creep at high temperature.

Routine corrosion tests are carried out by the Corrosion Section by various techniques, including total immersion in salt solution, salt-spray and atmospheric exposure. Specimens of various alloys treated in different ways are frequently supplied to various users, Government Departments, etc., for inclusion in their corrosion test programmes. The section also collaborates with F. A. Hughes & Co. in the development of cathodic protection.

The X-ray Section contains separate radiographic and crystallographic units. The former is naturally used mainly in radiography of production castings made by the Sand Foundry. The latter unit has proved invaluable for the identification of small amounts of substances, particularly in the investigation of fluxes and alloying processes, and the films of standard substances and materials available for comparison now number well over a thousand.

Sponsored Research Contracts

Both the Metallurgical and Chemical Research Departments carry out a number of research projects sponsored by Government Departments or other official bodies. The subjects cover a wide field, but relate to work in which the Company has a direct interest, or for which it is well equipped. Such contract work assists in keeping specialised teams in being, broadens the activities of the Department, and enables greater effort to be devoted to problems of special urgency as they may arise.

Conclusion

It is hoped that this brief survey of some of the research and development projects which the Department how has in hand will show clearly the the Company is not content to rest on any past achievements but will strive to maintain a leading position in the magnesium field and continue to provide the best possible technical service to its licensees.

* Modern Concepts in the Protection of Magnesium Base Alloys by Dr. W. F. Higgins, to be published in the September issue.

European Steel Market

E.C.E. Report Refers to Healthy Condition

EUROPEAN steel production and demand have been growing steadily in the last year, and the steel market is in a "healthy state" according to the Secretariat of the United Nations Economic Commission for Europe (E.C.E.), whose report* states that if there is to be a continuing and growing expansion of economic activity in the years to come, it may well be that the rate of growth of steel capacity envisaged in certain European countries is on the low side. The Secretariat suggests that "perhaps, therefore, the time has come when investment plans of the European steel industry as a whole should be the subject of renewed consideration."

Production Developments

In the main, 1953 was a year of some difficulties for the continental steel producers, although the market remained strong in the United Kingdom, but by the end of the year signs were apparent of an upturn in the market. This improvement gathered strength during 1954, and in the second half of the year boom conditions prevailed, with record outputs in most countries.

The rise in demand in 1954 in continental Western Europe was a result of a rapid improvement in economic conditions which reversed the 1953 de-stocking movement. While admitting the difficulties in appraising how the market will react in 1955, the Secretariat suggests that there is no prospect of an immediate change. This is supported by the fact that, in general, those indices available for production in the metal-using and construction industries show an upward trend, and there has recently been some tendency for steel prices to rise in view of the pressure of demand. On the other hand, it would not appear that orders on the books are unusually high, and such fragmentary information as is available on stocks indicates that these are not being abnormally run down.

In the U.S.S.R., steel production has continued to increase steadily, and the same is true of Poland. There was also some increase in Eastern Germany. In the other east European countries, however, steel production in 1954 either remained stable or fell slightly. The reasons for this uneven development are not altogether clear, but there appears to have been some realignment of steel production plans.

The increase in steel production in Europe during 1954 was not, in the main, impeded by shortage of supplies of raw materials, although east European figures might have been higher had more scrap been available. Scrap also began to be tight in western Europe about the middle of 1954. The situation was, however, relieved by imports of American scrap during the third and fourth quarters. These imports are continuing in 1955 although, with the rise in American steel production, licences for scrap exports are becoming more difficult to obtain.

Since the opening of the common market in the E.C.S.C. countries, there has been a rapid growth in trade in steel within this group. Some new post-war patterns of trade appear to be emerging, notably increased exports of steel from Belgium, Luxembourg and France/Saar to Western Germany. East-west trade in Europe in semi-finished and finished steel decreased during 1954 to only slightly over half the 1953 volume. There was, however, a relatively large increase in exports of Soviet pig-iron to western Europe which was a new development. The limited figures available suggest an increase in exports of iron ore from the Soviet Union to other east European countries, and a fairly stable trade amongst eastern countries in finished steel.

Planned Increases in Steel Capacity

The Secretariat reports that investment in the steel industry in western Europe as a whole was at a fairly high level during 1954, particularly in the United Kingdom and Western Germany, and that this is expected to continue. French investment may fall slightly in 1955 and subsequent years. In the United Kingdom and the E.C.S.C. countries the average annual compound increase in crude steel capacity is respectively estimated to be 4·7% and 2·7–4·1% up to 1958. For the smaller west European producers as a group, the equivalent percentage up to 1960 is estimated to be 4·3. In the U.S.S.R. the figure is considerably higher, and up to 1960 is estimated as 6·6%. It should be remembered, however, that while steel consumption *per capita* in the U.S.S.R. is approximately the same as in the E.C.S.C. countries as a whole, it is far lower than in, for example, highly industrialized countries such as the United Kingdom and Western Germany.

Supplies of raw materials should be available in sufficient quantity to match the steel expansion envisaged, particularly since far-reaching steps to develop iron-ore production overseas are in train. A qualification however is that difficulties seem likely in future supplies of scrap. The Secretariat observes that this, in turn, poses the question whether the rate of increase of blast-furnace capacity, particularly in parts of Continental western Europe, is sufficiently high.

The trend for a growing proportion of personal income to become available for durable consumer goods seems likely to continue. This suggests that the demand for motor vehicles and household goods will continue to rise, "particularly if price reductions can be achieved through modernisation and rationalization."

Export Prospects

While the future course of indirect exports of steel naturally depends on the course of world trade, the general trend towards indirect steel exports becoming more important than direct steel exports seems likely to continue, the review suggests. Turning to prospects for direct steel exports from Europe as a whole, the report says it is possible that the long-term trend may be

* *The European Steel Market in 1954.* Prepared by the Secretariat of the U.N. Economic Commission for Europe. 146 pages, including 52 tables. Available at 7s. 6d. per copy, from all Sales Agents for United Nations Publications, including H.M. Stationery Office, P.O. Box 569, London, S.E.1.

a continuing decline in the proportion of steel exports to world steel production as such. On the other hand this might be affected, at least temporarily, by the intensified industrialization of vast under-developed areas in Asia and Latin America, where the present *per capita* consumption of steel is extremely low. This possibility exists in spite of the fact that there is a growing trend towards increased steel production in many parts of the world (an expansion from a production of about 223 million tons in 1954 to a capacity between 313 and 326 million tons by 1960 is predicted).

During the last two years demand for flat products has continued to grow and flat steel now accounts for some 40% of total rolled-steel output. The demand prospects for flat products in the coming years are "distinctly favourable" and there appears to be good grounds for revising upwards the expectations of two or three years ago.

Gasification of Heavy Fuel Oil

O.C.C.R. Equipment to be Made in U.K.

THE "Office Central de Chauffe Rationnelle" (Central Organisation for the Economic Use of Fuel), an Association formed in France by a number of industrialists with the support of public bodies, has invented a process and developed the necessary equipment for the gasification of liquid fuel. There are already about 100 of these O.C.C.R. gasifier installations in operation on the Continent, and a licence has been granted to The Wellman Smith Owen Engineering Corporation, Ltd., for the manufacture and sale of this type of equipment in Great Britain and the Commonwealth countries.

Heating of furnaces often presents difficult problems relating to flame length and formation, temperature distribution, and the nature of the furnace atmosphere. Progress towards the solution of these problems, particularly the nature of the furnace atmosphere, is achieved by the combustion of the products resulting from the gasification of liquid fuel, instead of burning the liquid fuel directly.

The combustion of gasified fuel oil takes place in two steps, the first being a gasification of the oil fuel by the application of primary air and the utilisation of the heat of some of the constituents produced in the process. The second stage is the combustion of the resulting gas and finely suspended carbon matter with a supply of secondary air at the furnace.

Description of the Gasifier

The gasifier, as shown by Figs. 1 and 2, consists of a small vertical cylindrical shaft, into the base of which oil and primary air tuyeres are introduced. These are arranged at the periphery in such a manner as to impart a swirling spiral motion to the mixture of oil and gas. The volume of primary air introduced is controlled in relation to the amount of fuel oil supplied to the gasifier. The pressure in the primary air ring main, from which the air tuyeres are supplied, governs the supply of oil to the gasifier chamber in the manner described below.

Oil is fed to the gasifier from a constant level oil tank situated above the equipment. The pressure in this tank is maintained at that prevailing in the primary air ring main and thus causes oil to be fed to the gasifier, through a calibrated orifice in the oil feed pipe, in direct ratio to the primary air pressure. By this arrangement, the oil/air ratio is constant for any given primary air pressure and preset orifice diameter. The products of this gasification process leave the top of the gasifier through a refractory-lined tube, and are led to one or more burners for combustion with secondary air in a furnace reasonably adjacent to the gasifier.

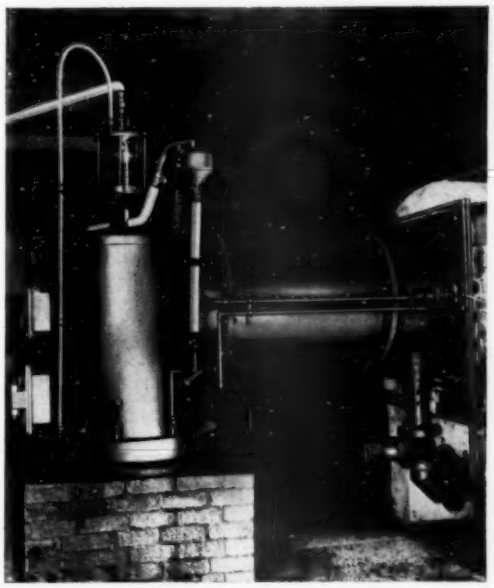


Fig. 1.—The O.C.C.R. gasifier equipment

All types of fuel oil, including heavy fuel oils, can be used in the gasifier, provided that the oil, before being supplied to the constant level tank, is heated to a temperature sufficient to give it a viscosity of 100°–150° Redwood No. 1.

Starting-up and Operation

A period of approximately half-an-hour is required to start the gasifier from cold. This length of time is sufficient to attain the necessary oil cracking temperature, at the end of which initial period it is possible to operate the gasifier and the burners at normal full load.

During operation, approximately 2–4% of the oil gasified (depending upon the nature of the fuel used) is deposited in the form of coke at the base of the gasifier. This deposit takes only a few minutes to remove, after 6–8 hours operation, and consequently does not cause any appreciable drop in furnace temperature. In the case of small capacity gasifiers, the primary and secondary air can be supplied from one fan. For larger size plant it is preferable to use two fans, one for primary and the other for secondary air, as primary air is supplied at a higher pressure than that of the secondary air.

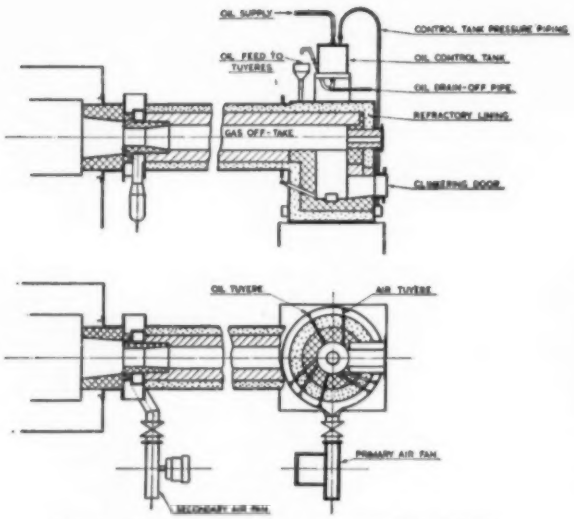


Fig. 2—Elevation and plan views of the gasifier

Principle of the Process

The products of the gasification of fuel oil depend mainly on the air/oil ratio. The higher this ratio the lower the resultant calorific value of the gas and the higher the temperature of the products leaving the gasifier. With a lower air/ oil ratio, the calorific value rises and the outlet temperature falls, but, due to the lower cracking efficiency, the amount of non-gasified suspended carbon increases. The final results of combustion are not, however, affected to any extent, due to the fact that the final combustion temperature is a product of the latent and sensible heat of the gas. Including the amount of suspended carbon, which is equivalent to about 30% of the carbon in the oil, the overall thermal efficiency is from 95% to 98%.

It will be realised that the oil gasifier is not a gas producer in the normal sense, but an oil cracking plant, and there is a fundamental difference between the oil gasifier process and the conventional gas producer. A gas producer using coal has a cold gas thermal efficiency of from 65% to 70%, and a hot gas thermal efficiency at the point of combustion of 75% to 80%. On the other hand, the losses from a heavy fuel oil gasifier amount to only 2–3% in respect of radiation, and 1–2% in respect of the coke deposited at the base of the gasifier. The Composition of the gas and the outlet temperature from the gasifier vary with the air/oil ratio.

The amount of primary air used in the process is approximately one third of the total air required for combustion of the oil, or about 60 cu. ft./lb. of fuel oil gasified. For a preset orifice size, the air/oil ratio remains constant and the rate of gasification is, therefore, entirely dependent on the primary air pressure. For a different air/oil ratio, a different diameter of orifice has to be used, the operation of changing this orifice being effected in a matter of a few minutes.

Approximate analysis of the gas produced would be as follows :—

CO_2	4%
CO	16%
H_2	14%
CH_4	4%
N_2	62%

The temperature of the gas produced is in the region of 1,150–1,250° C.

The heating value of the gas is made up as follows :—

	B.Th.U/cu. ft. at N.P.T.
Net calorific value of the gas	120
Sensible heat content	50
Heat in suspended carbon	45
Total heat value at producer outlet	215

Size and Application

O.C.C.R. fuel oil gasifiers can be supplied in varying capacities, ranging from 6 to 250 gallons per hour, having diameters of about 3 ft. for the smallest and 6ft. for the largest. Under normal conditions, the gasifier would have a turn-down range to 25% of its full capacity and if specially required it could be arranged to have a turn-down of ten to one by means of special modifications to the tuyeres.

This type of oil gasifier has been installed on a number of metallurgical furnaces, comprising about 48 installations on the Continent. Repeat orders have also been received which testify to the advantages of using fuel oil by this system. One of the chief advantages of the gasifier, as compared with the conventional burner, is its flexibility in being able to create a furnace atmosphere which is slightly reducing, neutral or oxidising This flexibility is not possible with an orthodox atomising type of oil burner which cannot be operated without 15 to 20% excess air. Furthermore, the normal atomising type of oil burner, however effective the atomisation of the fuel may be, invariably produces droplets, the deposition of which on the material being heated is considered to be the cause of most of the contamination from sulphur. It is claimed by the inventors of this process that in the case of combustion of gasified fuel oil, the sulphur attack is less than that from an orthodox burner, which claim is substantiated by results obtained from abroad. Tests are at present being carried out in conjunction with oil companies in this country to confirm this claim but, until the results of such tests are available, no definite statement can be made on the lower degree of sulphur attack obtainable from gaseous oil firing.

It should be mentioned that although Fig. 2 shows the gasifier feeding one burner only, in other cases a furnace may be equipped with a number of burners from one gasifier, and such burners would be designed to meet the requirements of the heating process to which the gasifier was being applied.

A pilot fuel oil gasifier firing into a combustion chamber has been erected at the Darlaston Works of The Wellman Smith Owen Engineering Corporation, Ltd., and is in operation from time to time to demonstrate the advantages of this process to those interested.

Correction

In the article on Exothermic Ferro-Chromium on page 37 of the July issue, there appeared the statement: "The relatively low ignition temperature is a safeguard against accidental combustion." This should, of course, be : "The relatively *high* ignition temperature . . ."

Change of Address

FROM 22nd August, 1955, the address of The Council of Industrial Design will be 28, Haymarket, London, S.W.1. Tel.: TRAfalgar 8000.

New Ring Rolling Plant at Steel, Peech & Tozer

View of the 400 ton upsetting and piercing press, with the rotary hearth billet heating furnace in the background.

FOR many years, the Steel, Peech & Tozer branch of The United Steel Companies has produced ring forgings for the ball bearing industry and, more recently, for the aircraft industry. Hitherto, the work has been performed by steam hammer forging, a somewhat slow means of production. To enable the range of sizes to be increased and to improve the method of production, a new £90,000 ring rolling plant has been installed and is now in production.

The new plant, which is expected to produce rings at the rate of 60 per hour, is capable of dealing with work up to 2¼ cwt., and has a range in outside diameter from 5 in. to 50 in. If quantities are sufficiently large, rings can be rolled to intricate profile, thus saving considerable metal, as well as machining time. Rings of 5 in. diameter and under can still be produced under steam hammers or, again, where quantities permit, on a high output upset forging machine.

Items of plant in the new mill consist of: two annealing furnaces, two cold saws, one rotary hearth gas-fired heating furnace, one re-heating furnace (for use where necessary), one 400-ton forging and piercing press, one ring mill, and three air-operated chuck lathes.

Method of Operation

Round bar, from steel made at the company's Templeborough works, is supplied in lengths of from 12 to 15 ft. If necessary, these bars are charged into the bar annealing furnace and from there transferred to the cold saws, where blocks of the required weight are cut. The block weight is calculated from the finished ring weight, making due allowance for punching, scale and machining losses.

The blocks are charged as required into the rotary furnace by means of a magnetic charging machine. Here, they are heated to the requisite temperature, usually up to 1,200° C. The furnace hearth rotates, bringing the heated blocks to the discharge door, when a discharging machine picks them up singly and drops them on to a conveyor which takes them to the punching press. The first block, now being in position under the press, is centralised by a pair of hydraulically-operated arms and is forged down to the required width. This operation is followed instantly and automatically by a top punch which travels through the block to a predetermined depth. With the top punch in this position, a bottom punch is brought into action and travels upwards until the flow of metal stops. The distance between the punches at this stage forms the only discard. The top punch is then removed to its original position and the bottom punch continues upwards to remove the small slug to the top of the blank. A pusher arrangement then carries the pierced blank to a conveyor which, in turn, takes the blank to the rolling mill. Here, the blank is placed in position on the mill spindle and the necessary rolling is performed.

A team of five operators controls the charging and discharging of the rotary furnace, the forging press and the ring mill.

It is necessary, for some sizes of rings, to control the shape of the punched blank and, on these occasions, the blank is punched into a retaining ring which is designed to give the required blank shape.

After rolling, rings which require annealing are charged into a bogie type furnace. All rings are then conveyed to the chuck lathes by means of pallets and fork lift trucks. Here, the faces of the rings are cleaned up to size, after which final inspection for size and quality is performed, and the rings are then ready for despatch.

Rotary Hearth Furnace

The rotary hearth furnace and the charging and discharging machines were supplied by The International Furnace Equipment Co., Ltd. The furnace, which is fired by coke oven gas, has the following dimensions :—

	ft.	in.
Effective hearth width	3	9
Diameter over hearth	12	3
Height from floor level to hearth	3	0
Diameter over all steelwork	17	0

The roof is static and the main body of the furnace rotates. Automatic temperature control equipment is fitted, and the furnace is divided into soaking and heating zones. It is capable of heating 120 blocks per hour, which is more than the capacity of the mill.

Rolling a pierced blank on the new mill.

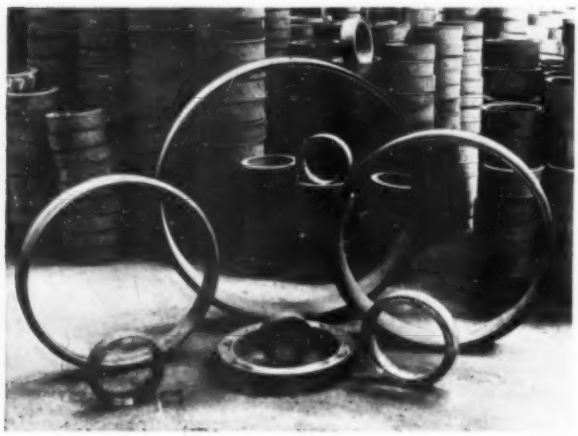
400-Ton Piercing Press

The upsetting and piercing press, of 400 tons capacity, was supplied by the Loewy Engineering Co., Ltd., and is capable of upsetting blanks to 12 in. diameter and 150 lb. weight. Blanks above this size and weight are produced on a large air hammer. The press is of conventional hydraulic design, being driven by pumps and air-loaded accumulator in order to make it operate as fast as possible. Performance details are as follows :—

Power of main ram	400 tons
Max. working pressure	2,850 lb./sq. in.
Stroke of main ram	24 in.
Lower punch power	150 tons
Lower punch stroke	15 in.
Power of two stripping rams	80 tons total

The punching arrangement on the press is not so conventional. Instead of using loose punches, the tooling is so arranged that a top and bottom fixed punch can be used. This enables one man to operate the punching process.

As described earlier, the top and bottom punches come together until the metal ceases to flow ; this enables the discard to be reduced to a minimum. When using $2\frac{1}{8}$ in. diameter punches, the discard can be reduced to 1 oz.



This picture gives an idea of the range of rings which can be rolled.

weight; when using larger diameter punches, the metal in the centre of the blank, being in contact with the cold punches, cools quicker and ceases to flow sooner, giving a slightly thicker and heavier discard. In other words, the discard increases in size and weight with the size of punch and corresponding loss of temperature. At its greatest, however, it is much less than the discard associated with traditional methods of ring forging.

Ring Mill

The ring mill, which, like the piercing press, is of Loewy design and manufacture, is compactly built and occupies comparatively little floor space. The maximum size ring which can be accommodated is 50 in. outside diameter, the maximum height being $9\frac{1}{2}$ in. Two people only are required to charge and control the mill.

A special and important feature, compared with conventional types of mill, is the possibility of using blanks with a small pierced hole. The smallest hole is $2\frac{1}{8}$ in. diameter, and it is thus possible to produce rolled rings beginning from approximately 4 in. inside diameter. For a larger ring, a 3 in. hole is used, and, for a ring of maximum size, a 4 in. hole is the starting point.

The machine consists, in the main, of a fabricated steel frame supporting the large roll-driving shaft and forming a slideway for a saddle which carries the small roll-driving shaft. The large outer roll and the inner roll of small diameter are each driven by their own electric motors, of 100 h.p. and 3 h.p., respectively, the latter rotating the small roll through bevel gears and vee rope. The vee ropes and pulleys may be interchanged to give four alternative speeds. The inner roll is carried top and bottom in a tapered cone, through which the necessary adjustment for ring width can be obtained.

The upper end of the spindle, which is supported in the top cone, is mounted on top of the machine and carried on a pivot shaft. The two rolls are brought together by means of a system of hydraulic cylinders. After each rolling operation, the pivoted arm is hydraulically lifted and swung out sideways, so that the next blank can be loaded into the mill. For the purpose of guiding the ring during rolling, a pair of rollers is placed on either side of the large roll. These side rollers are mounted in swinging arms and are actuated by the mill operator.

The final rolled ring size is checked by a gauging device, connected to a large dial. This device measures the diameter of the rolled ring by means of a roller, which contacts its outer circumference. The roller is carried on a downward extending arm attached to a spring-loaded sliding block. As the sliding carriage moves forward during rolling, the push rod attached to the extended arm makes contact with the mechanism of the circular dial. The dial indicates variations above and below the desired final diameter of the ring at an increased scale.

B.I.C.C. Travelling Scholarship—

British Insulated Callender's Cables, Ltd., have instituted a Travelling Scholarship as a tribute to Sir Alexander Roger, K.C.I.E., for many years chairman of the company and now its first honorary president. It will be known as the Sir Alexander Roger Travelling Scholarship. With a value up to £1,000, in addition to normal emoluments, it will be awarded annually to an employee of B.I.C.C., and will enable a young man or woman of ability to travel overseas for study, training and general education for a period of a year.

NEWS AND ANNOUNCEMENTS

Iron and Steel Institute

Special Meeting in Scunthorpe

THE Council of The Iron and Steel Institute have accepted an invitation from The Lincolnshire Iron and Steel Institute to hold a Special Meeting in Scunthorpe from Wednesday, 12th, to Friday 14th October, 1955. A Reception Committee has been formed in Scunthorpe, under the Chairmanship of Lieutenant-Commander G. W. Wells, R.N. (Retd.), D.L., President of The Lincolnshire Iron and Steel Institute; a Ladies' Committee has also been formed of which Mrs. G. W. Wells has kindly consented to act as Chairman.

The meeting will follow the usual pattern, in that it will include technical sessions, works visits and social functions. The technical papers to be discussed include "Developments in Ironmaking at Appleby-Frodingham" by G. D. Elliott, O.B.E.; "The Expansion Scheme at John Lysaght's Scunthorpe Works, Ltd.", by W. L. James; "Steelmaking at Redbourn", by S. R. Isaac; "Organization for Maintenance", by J. L. Gaskell; "Underground Mining of the Frodingham Ironstone Bed at the Dragonby Mine, Scunthorpe", by C. Smith; and "Development of Chemical Methods for the Treatment of Low-Grade Ores at Appleby-Frodingham", by L. Reeve. Works visits will be made to blast furnace, open hearth and rolling mill plant of the Appleby-Frodingham Steel Co., John Lysaght's Scunthorpe Works, Ltd., and Richard Thomas and Baldwins, Ltd., Redbourn Works, and to the steel foundry of Thos. Firth and John Brown, Ltd., and the Dragonby Ironstone Mine of The United Steel Cos., Ltd.

On the Wednesday evening there will be a Reception and Buffet Supper at the Baths Hall, Scunthorpe, by invitation of the Mayor and Corporation of Scunthorpe, and on Thursday evening, by invitation of The Lincolnshire Iron and Steel Institute, there will be a Dinner and Dance at Elsham Hall (by kind permission of Capt. J. Elwes).

Institute of Metals

Students' Essay Competition

THE Council of the Institute of Metals will award two prizes for the best essays submitted in the Institute's Student Essay Competition. There will be a first and a second prize of twenty-five guineas and fifteen guineas, respectively, half of each of which will take the form of appropriate books, to be selected by the prizewinners.

The competition is open to all Student Members of the Institute, to all Associate Members of Local Sections and to all members of Associated Societies (Leeds Metallurgical Society, Liverpool Metallurgical Society, Manchester Metallurgical Society and North-East Metallurgical Society) who are eligible for Student membership of the Institute, provided that they are within the normal age limits for Student membership, viz. 17–25 years. The competition is not restricted to persons who are undergoing courses at a university or technical college.

The choice of subject is left to the competitors, except that subjects relating exclusively to extraction or ferrous metallurgy are ineligible. It is intended, though this may be varied as may be found necessary, that one prize shall be awarded for a paper on a theoretical subject and the other for a paper on a practical subject. The subject matter should be logically presented, in good English, and should have a metallurgical content to impress the adjudicators by soundness, exercise of critical faculty, and originality of approach. Essays should be 2,500–3,500 words long, and must not exceed 3,500 words.

Each entry must be submitted, not later than 1st January, 1956, to The Secretary, The Institute of Metals, 4 Grosvenor Gardens, London, S.W.1., from whom full particulars of the regulations governing the competition may be obtained.

International Hardness Measurement Conference in Bremen

THE Arbeitsgemeinschaft für Fertigungstechnisches Messwesen AFM (Working Committee for Metrology in Production) of the V.D.I. and the Institut für Härteprüftechnik (Institute for Hardness Testing Technology) are arranging a Second International Conference on "Hardness Measurement in the Works" on September 22nd and 23rd, 1955, in Bremen, in connection with an exhibition of modern hardness measuring equipment of German and foreign manufacture.

The first International Conference in Bremen, in September 1952, and the Hardness Testing Conference in Sheffield in 1953, have shown that in the field of hardness measurement in the works a number of urgent problems occur in all industrial countries. These meetings provided opportunity for a valuable exchange of experiences and served to foster collaboration between experts in different countries. Further, a valuable contribution to the establishment of internationally comparable hardness values was made—a step of some importance to the import and export trade in technical products.

In the meantime further considerable research and development work has been carried out, and in contributions from the U.S.A., United Kingdom, France, Japan, Austria and Germany, actual problems of hardness measurement by various types of equipment will be discussed, together with hardness measurement on internal surfaces,and the possibilities of using statistics in the field of hardness testing.

Symposium on Mineral Resources Policy

A MEETING to discuss a minerals policy for the United Kingdom is being arranged by the Institution of Mining and Metallurgy, to take place on Thursday, 22nd September, 1955, at the Hall of the Royal Society of Arts, John Adam Street, Adelphi, Strand, London, W.C.2. Two sessions are being arranged: 10 a.m.–12.30 p.m., and 2 p.m.–4.30 p.m.

Members of the Institution and others concerned with the mineral resources of the British Commonwealth will be asked to consider whether some co-ordination of effort at every stage of production would be desirable to conserve supplies or expand output to the best advantage, and to propose how such aims might best be achieved.

An Office of Materials Mobilisation has been established in the United States of America with similar objects, and proposals for setting up a comparable organisation have been put forward in the United Kingdom from time to time.

The object of the symposium is to allow fuller discussion of the proposals contained in a paper entitled " Mineral Resources Strategy ", by Mr. D. A. Oliver, C.B.E., Director of the B.S.A. Group Research Centre. This paper was first submitted at a conference on Research and Industrial Productivity held in London in November, 1954, and the theme is " that minerals productivity will be increased if greater co-ordination of the right kind can be established between all the interested parties "—geologists, mineral dressing and mining specialists, mining and finance houses, mining engineers, local territorial authorities, fabricators and users, and, finally, Government. Other papers to be discussed include " Mineral Development and Research in the U.S.A. and Canada " ; " Aspects of the Mineral Industry in East Africa " ; " How Canada Aids its Mineral Industry " ; " Some Economic Considerations in a British Mineral Resources Policy " ; and " Proposal for a Central Ore-Dressing Laboratory ".

Non-members wishing to have full details of the meeting and advance copies of the papers are asked to write as soon as possible to the Secretary, The Institution of Mining and Metallurgy, Salisbury House, Finsbury Circus, London, E.C.2. (We are advised that the office and library of the Institution will move to 44, Portland Place, London, W.1., early in September).

Advanced Lecture Courses

ADVANCED courses of lectures on subjects of metallurgical interest will be held in the Department of Applied Chemistry, Northampton Polytechnic, St. John Street, London, E.C.1. in the autumn.

On Thursday evenings at 7 p.m., from 29th September to 3rd November, there will be a series of lectures on " Foundry Sands ; Their Properties, Testing and Applications." The lecturer will be Dr. J. E. Garside, and the fee is 10s.

" Ceramics : A Survey of Their Characteristics and Applications" is the title of a course to be held on Tuesday evenings at 7 p.m., from 11th October, to 6th December, when the lecturers will include Dr. A. J. E. Welch, Mr. L. R. Barrett, Mr. J. P. Roberts, Mr. B. E. Waye, and Dr. J. W. Tomlinson. The fee for this course is 20s.

Finally, on Monday evenings at 7 p.m., from 3rd October to 14th November, there will be a course on " Research and Investigational Methods in Corrosion Science ". The lecturers will include Dr. F. Wormwell, Mr. A. U Evans, Dr. G. Butler, Dr. P. T. Gilbert, Mr. T. W. Farrer and Dr. F. A. Champion. The fee for this course is 10s.

Practical X-Ray Crystallography Course

A COURSE in " Practical X-Ray Crystallography " will be held in the Physics Department of Battersea Polytechnic commencing on Tuesday, 11th October, 1955. The course will include lectures, demonstrations and practical work, totalling some 54 hours, and will include such aspects of the subject as the operation of gas and vacuum X-ray equipment ; the use of standard X-ray cameras ; single crystal powder and back reflection methods ; and interpretation of photographs.

The course is intended for graduates and others suitably qualified who require practical experience in this field, and further details can be obtained from the Head of the Department of Physics, Battersea Polytechnic, Battersea Park Road, London, S.W.11 : the fee is £2 10 0d.

Edwards Italian Subsidiary

SINCE moving to Crawley, Edwards High Vacuum, Ltd., have made great efforts to increase the export side of their business throughout the world, and to consolidate their progress in Canada, W. Edwards & Co. (Canada) was formed some 18 months ago.

Europe is, however, no less important, and the Company now announces the formation of an Italian subsidiary, Edwards Alto Vuoto S.p.A., which will have offices in Milan. The Company has been formed in conjunction with Societa Apparecchi Elettrici E Scientifici who acted as their agent for many years. Through them a considerable amount of vacuum equipment has already been supplied, especially to the electronics industry.

Wickman, Ltd.

WICKMAN, LTD., have been appointed sole representatives in the United Kingdom of the following firms : (1) Eumuco Aktiengesellschaft für Maschinenbau, Leverkusen, Germany—hydraulic and mechanical forging machine specialists and manufacturers of drop hammers, forging rolls, forging and upsetting machines and forging presses ; (2) Nagel Maschinen und Werkzeugfabrik G.m.b.H., Nurtingen/Württ, Germany—manufacturers of vertical and horizontal honing machines, super-finishing machines for brake drums, and super-finishing spindles.

Personal News

MAJOR C. J. P. BALL, D.S.O., M.C., who has held the post of Chairman and Managing Director of Magnesium Elektron, Ltd., from the Company's formation in 1934, has relinquished the latter appointment in favour of DR. C. J. SMITHELLS, M.C., but remains as Chairman of the Company. BRIG. A. C. COLE, O.B.E., previously Assistant Managing Director, has been appointed Commercial Director. DR. S. J. FLETCHER remains Technical Director.

MR. A. D. BUSBY, who has been a member of the Development and Research Department of The Mond Nickel Co., Ltd., for 18 years—first in the Research Laboratory, Birmingham, and for the last five years as Development Metallurgist on alloy and special cast irons—has resigned his position, in order to take up the post of Deputy Process Development Manager of the Titanium Department, I.C.I. (Metals), Ltd., Witton, Birmingham.

BABCOCK & WILCOX, LTD., announce the retirement of MR. J. SMITH as Managing Director of Edwin Danks & Co., (Oldbury), Ltd.: he has been appointed Deputy Chairman of the Company from 1st July, 1955. MR. L. W. H. REA, whose appointment as General Manager of Edwin Danks has been previously announced, has been appointed to the Managing Directorship.

MR. I. LLOYD has retired as Vice-Chairman and Joint Managing Director and from the Board of The Expert Tool and Case Hardening Co., Ltd., of which Company he was the founder. His services, however, have been retained in a consultative capacity.

THE DISTINGTON ENGINEERING CO., LTD., announce that MR. J. M. L. HOWELL has been appointed Sales Manager (Earth Moving).

THE INTERNATIONAL MEEHANITE METAL CO., LTD., announce that MR. P. ATTENBOROUGH, MR. G. HOBMAN and MR. E. W. HARDING have been appointed to their Board of Directors, with MR E. M. CURRIE as Managing Director.

MR. P. E. HOLLOWAY has been appointed to the Board of Directors of The Wellman Smith Owen Engineering Corporation, Ltd. He is also a Director of one of the leading British steel companies.

MR. T. WATSON, a Director of General Refractories, Ltd., of Sheffield, has been elected President of the Refractories Association of Great Britain for the ensuing year. Mr. Watson is also a Director of United Sands, Ltd., Unifax, Ltd., and Associated Silicas, Ltd.

MR. R. J. GLINN has retired after 44 years with Babcock & Wilcox, Ltd. He has also retired from the Board of the Calorizing Corporation, of which he has been a Director since 1928.

MR. L. W. JOHNSON has been appointed Assistant Manager of the Development and Research Department of The Mond Nickel Co., Ltd., and DR. E. C. RHODES has been appointed Assistant to the Manager of the department. He will make his headquarters at Thames House, but will remain responsible for D. & R. Precious Metals activities at Acton.

THE ever-growing importance of oxygen in the aircraft industry of this jet age is reflected in an announcement by British Oxygen, who have appointed Air Vice-Marshal D. V. CARNEGIE, C.B., C.B.E., A.F.C., to carry out, on behalf of the Company, liaison duties with the armed forces and Government departments.

THE HON. MICHAEL LAYTON has joined the staff of Guest Keen Iron & Steel Co., Ltd., as Assistant to the Joint Managing Directors.

GENERAL REFRACTORIES, LTD., Genefax House, Sheffield, announce that as from 1st July, 1955, MR. B. EICHLER, has been appointed Director of Research—Silica and Aluminous Division, and MR. H. PARNHAM, Director of Research, Basic Division, at their Group Central Research Laboratories, Worksop.

MR. A. W. HANSON, until recently Manager of the Karachi Office of Babcock & Wilcox, Ltd., has been appointed by the Company to the Managership of their Newcastle Office. MR. P. R. BETTLE is his Deputy.

MCKECHNIE BROTHERS, LTD., have pleasure in announcing the appointment of MR. W. D. MCKECHNIE as Sales Manager (Lithopone). Mr. McKechnie previously held the post of Assistant Sales Manager for this pigment.

TUBE INVESTMENTS announce that on reaching retirement age MAJOR W. F. F. SCOTT, M.C., Director of Training and Welfare retired from the Board and relinquished his appointments within the Company on 31st July, 1955.

THE Governors of the College of Aeronautics have appointed PROFESSOR A. J. MURPHY as Principal of the College. He will take up his appointment on October 1st next. After almost 20 years with J. Stone & Co., Ltd., as Chief Metallurgist and later as Director, Professor Murphy was appointed Professor of Industrial Metallurgy at the University of Birmingham five years ago, and since 1953 has been Director of the Departments of Physical Metallurgy and Industrial Metallurgy.

MR. B. B. GREEN, M.C., and MR. W. J. MCBRIDE have been appointed to the Board of Directors of Edgar Allen & Co., Ltd.

MR. D. G. WELTON has left the Stoke-on-Trent Sub-Office of The English Electric Co., Ltd., to take up an appointment in the London Branch Office. He is succeeded at Stoke by MR. R. EDWARDS, formerly of the Birmingham Branch Office.

MR. G. W. TURTON, formerly with Hopkinsons, Ltd., Huddersfield, has been appointed General Manager of J. H. Humphreys & Sons, Ltd.

MR. P. J. A. TURNER, Chief Engineer of the Company's Glasgow factory, has been appointed to the Board of Kelvin & Hughes (Industrial), Ltd., and MR. H. R. WHITFIELD, Chief Radar Engineer, and MR. R. M. STEPHENSON, Overseas Sales Manager, become Directors of Kelvin Hughes (Marine), Ltd. Appointments to the Board of Kelvin & Hughes (Aviation), Ltd., include MR. F. W. BATES, who was recently appointed to the Board of the parent Company, Kelvin & Hughes, Ltd.; MR. R. W. DUNN, who is Chief Engineer (Aviation Instrument); MR. D. H. PERKINS, Works Manager, Basingstoke; and MR. G. WIKKENHAUSER, Chief Development Engineer at the Company's Barkinside factory.

MR. H. BORROWDALE who has retired from the position of Chief Draughtsman of the Trackwork Department of Edgar Allen & Co., Ltd., has been a member of the department for 42 years.

RECENT changes in policy and organisation at Foundry Services, Ltd., have resulted in the following appointments being made: MR. R. D. HUME, Deputy Managing Director and Works Director; MR. R. A. MILLER, Director, with executive duties as Sales Manager; MR. G. E. COBBY, Director, with executive duties as Chief Accountant; DR. D. V. ATTERTON, Technical Manager; MR. R. F. BODDEY, Deputy Technical Manager. MR. R. A. MILLER has been appointed Director, MR. G. E. COBBY, Secretary, and MR. D. A. J. PATTERSON, Manager, Overseas Manufacturing and Export Sales of Foundry Services (Overseas), Ltd. DR. K. STRAUSS and MR. E. WEISS remain as Chairman and Managing Director, respectively, of both Companies.

IN view of the impending retirement of SIR HAROLD WEST, Managing Director of Newton, Chambers & Co., Ltd., MR. P. J. C. BOVILL, an Assistant Managing Director and General Manager of the Chemicals Division, has been appointed a member of the Board, with a view to his eventually succeeding Sir Harold as Managing Director.

Obituary

We regret to record the deaths of the following:

MR. R. H. HUDSON, London Area Manager of John Holroyd & Co., Ltd., who died on 17th July, 1955, whilst on holiday in Majorca.

MR. E. ROTHERHAM, Manager of the Hacksaw Department of Sanderson Brothers & Newbould, Ltd., who died on 9th June, at the age of 54.

MR. J. R. MAGEE who died on the 16th June, 1955. Mr. Magee had for the past 12 years been technical representative in Scotland of Armstrong Whitworth (Metal Industries), Ltd.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

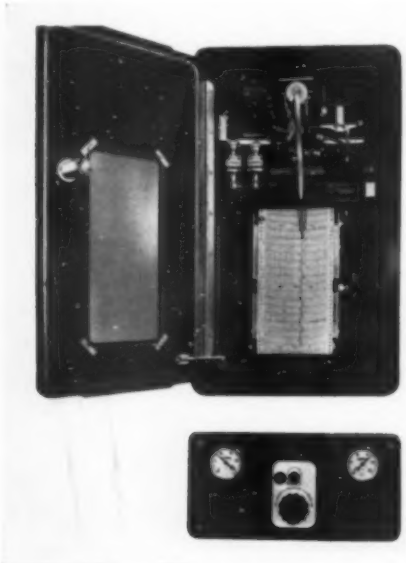
Wobbe Index Controller

The Sigma-Kent Wobbe Index Controller, just released, affords control of supplies of town's gas in factories to a desired Wobbe number, by automatically adding a small amount of air to the incoming gas, or by trimming the output of a mechanical mixing machine by an additional supply of gas. The Wobbe index is a function of calorific value and specific gravity, and the new controller, a combination of the Sigma Wobbe index recorder and the Kent Mark 20 air-operated controller, enables corrections to be made for changes in both calorific value and specific gravity.

The measuring instrument, the Wobbe recorder, is made by the Sigma Instrument Co., Ltd. of Letchworth, and the Mark 20 pneumatic controller by George Kent, Ltd. of Luton. The recorder is designed especially for control purposes and has a very high rate of response. It consists of three main components: flow regulator, heat exchanger, and flow recorder. The function of the flow regulator is to supply gas to a burner in the heat exchanger at a constant pressure. The amount of heat developed by a gas burner in any given time depends on four factors: (1) the size of the orifice controlling the discharge of gas; (2) the differential pressure across the orifice, i.e., gas pressure; (3) the calorific value of the gas; and (4) the specific gravity of the gas.

If the size of the orifice in the line to the burner is constant, and the regulator maintains a constant differential pressure across the orifice, the heat released from the burner is directly proportional to the calorific value and inversely proportional to the square root of the specific gravity. Heat input to the work therefore varies as the Wobbe index.

The heat exchanger consists of two concentric vertical steel tubes through which the products of combustion pass to atmosphere. The lower ends of both tubes are rigidly joined together, the upper end of the outer tube being fixed to the instrument case. A bar attached to the upper end of the inner tube transmits the relative expansion or contraction of the inner tube to the recording linkage. This relative movement is directly consequent on changes in the Wobbe index of the gas being burned, ambient-temperature changes having no effect on the apparatus.



The Kent Mark 20 pneumatic controller is mounted within the instrument case, and is arranged to detect the smallest deviation of the recording pen from the desired-value setting pointer through a differential linkage system. The controller mechanism translates the deviation into a change in air pressure in the automatic-control system, which embodies proportional, integral and first-derivative functions of the deviation. This pressure is used to re-position a regulating valve controlling the addition of air or of gas in the mixing system, thus restoring the Wobbe index of the gas supply to the desired value in the shortest possible time.

Experiments with an exothermic furnace-atmosphere generator have shown that great precision of furnace-atmosphere composition can be obtained by controlling the gas mixture to the combustion chamber at a fixed Wobbe index value.

George Kent, Ltd., Luton, Bedfordshire.

Small Bore Gauges

BATY have now added to their already well-known range of bore measuring instruments a successful small hole gauge with a capacity of $\frac{3}{8}$–$\frac{1}{2}$ in. The construction of a small bore indicating gauge, which will repeat to 0·0001 in., has always presented a problem owing to the limit placed on size by the confined space in which the instrument must work. Not only must the gauge incorporate a satisfactory means of transmitting contact plunger movement to the indicator, but it must also have an arrangement for centralising itself in the bore. Various transmission and centralising methods have been developed at times, but have failed to give the necessary accuracy and repeatability or have resulted in a gauge with an inconveniently small range.

The Baty Nos. 200 and 202 are accurate gauging instruments reading faithfully to 0·0001 in. and being purely mechanical, with no dependence on air or electricity, they are simple, positive and reliable. The mechanism, while robust, responds freely under light contact pressure, and has that sensitivity so essential for accurate measurement. As with the other Baty bore gauges, a shoe, independent of the measuring contacts, centralises the gauge in a bore. There are no expensive interchangeable measuring heads, the range being obtained by a small series of extension rods. The gauge is light, easy to use and is equally at home on the bench or at the machine. It is supplied in two forms—with straight or right angle holders—and with readings of 0·0005 in., 0·0001 in. and 0·01 mm. The straight holder is available in two sizes; one for bores $1\frac{1}{2}$ in.

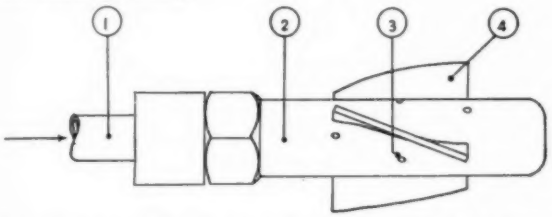
deep and the other for bores 2½ in. deep. The right angle holder is suitable for bores 1 in. deep, and is designed for operation where space in front of the hole is limited. It has an average height of 5½ in. and requires a space of only 2 in. for insertion into the bore.

J. E. Baty & Co., Ltd., 39 *Victoria Street, London, S.W.*1.

Flame Cleaning of Tubes

A new method of cleaning the insides of tubes which will have a wide application and give considerable advantages in speed and efficiency is indicated by a report on maintenance work carried out recently at the Prince Regent Tar Co. The tubes involved in this particular job were still tubes used in the coal tar distillation process. In service these tend to become fouled by deposits of bitumen, and cleaning is normally a tedious job undertaken with a mechanical drill and scraper. In some cases it may take a full day to clear one tube.

The new method, which was tried out with complete success, reduced cleaning time from one day to 30 minutes. The apparatus was an adaption of British Oxygen's flame cleaning equipment. The still tubes in question were cast iron, 15 ft. in length and 2 in. bore, and a simple burner was designed with integral fins, which, besides spacing the burner from the wall of the tube, acted to some extent as scrapers. This fitted into the bore so that the whole length of the tube could be traversed internally.



1 Oxygen Inlet. 2 Burner Body. 3 Radial Ports. 4 Radial Blades.

During earlier attempts to burn out the residue, too much heat was applied to the casting but it was noted that at one stage of the proceedings, the gummy bitumen turned into a form of powdery coke, and that this material was easily removed by scraping. In view of this, the burner which was constructed had only a few $\frac{1}{16}$ in. holes drilled into it for gas nozzles, and these were sufficient to bring about the required conditions. The assembly was attached to an ordinary piece of lance tubing through which the gases were supplied, and it was then possible to push the assembly progressively through all the obstructions. Alternate passes with this burner and a scraper proved adequate to remove all deposits.

Although no excess of heat is applied to the pipe being cleaned, the burner itself attains a red heat in a very short time and must, therefore, be constructed in stainless steel. It is also necessary to use a short length of stainless steel tube between the burner and the lance pipe, otherwise their life is very short.

*The British Oxygen Co., Ltd., Bridgewater House, Cleveland Row, St. James's, London, S.W.*1.

Oxygen Meter

A NEW oxygen meter which can readily detect changes in oxygen concentration of 0·5 volume per million, was shown for the first time at the Instrument Industries' Exhibition. Known as the Hersch Oxygen Meter, the apparatus has been developed by the Baker Platinum Division of Engelhard Industries, Ltd.

The meter will continuously measure traces of oxygen present as an impurity in other gases, and although it fulfils much the same function as the existing Deoxo Indicator it is very much more sensitive and covers the range 0–100 volumes per million. At maximum sensitivity, the full scale deflection on the 10-in. scale of the meter represents 10 v.p.m., so that changes in oxygen concentration of only 0·5 v.p.m. can be readily detected. The accuracy of the indication is claimed to be less than ± 5% of full scale deflection, and the response of the instrument to changes in oxygen concentration is almost instantaneous.

The Hersch oxygen meter, which measures approximately 24 in. high × 18 in. wide × 12 in. deep, will be useful in many metallurgical and chemical processes where the maintenance of an oxygen-free atmosphere is essential.

Baker Platinum Division of Engelhard Industries, Ltd., 52 *High Holborn, London, W.C.*1.

Easy-Flow Paint

Easy-flo silver brazing alloy is now available in a new form. In certain brazing applications, the nature of the assembly is such that a paste preparation is more convenient than brazing material in one of the more familiar solid forms. Easy-flo paint, consisting of a mixture of finely divided Easy-flo metal powder and flux in a liquid medium, has been produced to meet such requirements. It will satisfactorily braze a wide range of materials, and can be used with any of the various methods of heating in general use. Full details of Easy-flo paint are given in Data Sheet 2129, available free on request.

Johnson Matthey & Co., Ltd., 73–83 *Hatton Garden, London, E.C.*1.

CURRENT LITERATURE

Trade Publications

THROUGHOUT the chemical and engineering industries, uncontrolled water vapour interferes with process controls and adds to maintenance costs. A recent brochure, issued by Birlec, Ltd., explains how the incorporation of a standard Birlec Lectrodryer in the air or gas flow can remove water vapour. Typical installations are illustrated, and amongst the applications thus shown are the drying of compressed air for blowing chlorine tanks, air drying to facilitate drying out refrigerator compressor assemblies, and the drying of annealing furnace atmospheres in a wire mill. In addition, Lectrodryers are widely installed for drying compressed air supplies for instrument operation. They operate on the simple principle of adsorption by "activated alumina," and by the use of two or more beds of alumina continuous drying can be provided. In the dual adsorber, with which the latest Birlec publication mainly deals, one bed is engaged on drying whilst the other is being "reactivated" for future use. Automatic change-over of function is one feature of design frequently employed.

A NEW publication issued by Henry Wiggin & Co., Ltd., describes and illustrates some of the uses of wrought nickel and nickel alloys in electronic valves. Tabular data on physical and electrical properties demonstrate the suitability of the various grades of wrought nickel to meet specific requirements in individual components. Copies may be obtained, without charge, from The Publications Department of the Company at Thames House, Millbank, London, S.W.1.

MORGOIL roll neck bearings are featured in a new publication of Davy and United Engineering Co., Ltd. They are based on the hydrodynamic principle that an amply lubricated shaft creates a high pressure oil wedge in the load zone of the bearing, completely eliminating metal to metal contact. Oil is continuously pumped into the bearing to satisfy this condition. The pamphlet discusses the features of this type of bearing and its applications, being illustrated with cut-away drawings. It concludes with details of the range of sizes and capacities, and illustrations of installations incorporating Morgoil bearings.

FIELDEN ELECTRONICS, LTD., of Wythenshawe, Manchester, have sent us an advance copy of a 30-page booklet produced by their Technical Publications Department entitled "Level Control—The Application of Electronic Capacity Relays to Industrial Level Indication." The publication describes in detail the use of the well-known "Tektor" for level control of various fluids and powders, in vessels, containers, conveyors, chutes, etc., with schematic diagrams, fixing details, circuits, etc. It was compiled to assist users of Fielden equipment but anyone interested in the subject of level control will find the booklet of considerable value, and a copy can be obtained from Fielden's Level Division by mentioning this journal.

A LEAFLET, issued by Henry Wiggin & Co., Ltd., describes the Brightray series of electrical resistance materials, and gives brief notes on the type of service for which each grade is intended. Introduced more than 30 years ago, new grades have been brought into production as a result of continual research to provide improved materials. The latest addition is Brightray "H" which is suitable for furnace elements operating in the range 1,100–1,250° C. The complete range provides materials especially suitable for service in various conditions, meeting requirements in electrical resistances in practically all types of domestic and industrial heating apparatus. Copies of this leaflet are available from The Publications Department of the Company at Thames House, Millbank, London, S.W.1.

Books Received

"Physical Chemistry and Metal Extraction." By D. W. Hopkins. 232 pp. inc. author and subject indexes. London, 1954. J. Garnet Miller, Ltd. 30s. net.

"Titanium in Iron and Steel." By George F. Comstock. 294 pp. inc. name and subject indexes. New York and London, 1955. John Wiley and Sons, Inc., and Chapman and Hall, Ltd. 48s. net.

"Materials of Construction: Their Manufacture and Properties." By Adelbert P. Mills, Harrison W. Hayward and Lloyd F. Rader. Sixth edition. 650 pp. inc. index. New York and London, 1955. John Wiley and Sons, Inc., and Chapman and Hall, Ltd. 60s. net.

"Electric Melting and Smelting Practice." By A. G. E. Robiette. 347 pp. inc. index and numerous illustrations. London, 1955. Charles Griffin and Co., Ltd. 50s. net. By post 1s. 3d. extra.

"Aciers Inoxydables, Aciers Réfractaires." By L. Colombier and J. Hochmann. Preface by H. Malcor. 526 pp. inc. author and subject indexes and numerous illustrations. Paris, 1955. Dunod.

English-German and German-English Dictionary for the Iron and Steel Industry. By Eduard L. Köhler, Assisted by Priv.-Doz. Dr. mont. Alois Legat. 162 pp. Vienna, 1955. Springer-Verlag. 47s. 6d.

"X-ray Diffraction by Polycrystalline Materials." Technical Editors: H. S. Peiser, H. P. Rooksby and A. J. C. Wilson. (Physics in Industry Series). 725 pp. inc. subject and name indexes and numerous illustrations. London, 1955. The Institute of Physics. 63s.

£10 Million Contract for Boiler Plant

INTERNATIONAL COMBUSTION have received an order from the British Electricity Authority for three of the largest water-tube boilers in Europe, operating under the most advanced conditions of steam pressure and temperature in this country. So far as is known, this contract, the value of which approaches £10 million, is the largest single contract for boiler plant ever placed in this country and will provide work for some five to six years ahead.

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
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The Decomposition of Blast Furnace Raw Materials and Slags, Steelmaking Slags and Refractories for the Purpose of Chemical Analysis*

By E. W. Harpham

Richard Thomas and Baldwins Ltd., Ebbw Vale Works, Mon.

The chemical analysis of oxide-bearing materials can only be carried out successfully if complete decomposition of the sample is obtained. Methods for the decomposition of iron ores and related materials, slags and refractories of widely varying composition are referred to, and many of them described in detail. The first part of the paper, published last month, included a general discussion of the techniques used. In the concluding part presented here the application of the methods is considered.

4—APPLICATION OF THE METHODS

THE application of the methods described to the decomposition of the materials given in Section 2 will now be discussed. Many of these methods are well known and have been thoroughly investigated, for example, fusions with sodium carbonate or potassium bisulphate. Other decomposition procedures, such as certain of those used for the determination of ferrous iron, are not so widely known, nor have they received such a complete study. New and improved methods of decomposition for many substances would be very welcome to the chemist.

A—Iron- and Steelmaking Raw Materials

(a) Iron Ores, Sinters, Tap Cinder, etc.

The majority of the iron ores of commerce are almost completely decomposed by heating with hydrochloric acid, usually leaving only a small, white residue. This residue may not always consist entirely of silica and, if it is at all appreciable, it should be filtered off, ignited, fused with a suitable flux and added to the main solution. It is advantageous with the more highly siliceous materials to add a few drops of hydrofluoric acid to the hydrochloric acid solution. The presence of a little stannous chloride in the acid solution also assists in the acid decomposition of these materials when iron alone is being determined. If the ore contains appreciable amounts of carbonaceous matter, as, for example, certain black-band ironstones, it is recommended that, before the acid attack is carried out, or a fusion with sodium carbonate made, the carbonaceous matter be removed by ignition at as low a temperature as possible, and under good oxidising conditions. For certain iron ores and sinters which are incompletely attacked by hydrochloric acid, the insoluble residue remaining after a preliminary acid attack is filtered off, ignited, fused with either potassium bisulphate or sodium carbonate, and the resulting melt dissolved and added to the original solution. An attack by hydrochloric acid, or by mixed hydrochloric and nitric acids, followed by a sodium carbonate fusion of any insoluble residue, provides a suitable solution in which may be determined satisfactorily iron, silicon, phosphorus, aluminium, calcium and magnesium. The details of this method of decomposition as applied to iron ores are given in Appendix II. Titaniferous iron ores (for example, ilmenite) are usually not completely decomposed by a straight acid attack. These ores are better decomposed by a direct fusion with potassium bisulphate and solution of the melt in dilute sulphuric acid, especially if titanium is to be determined in the same solution.

A novel method for " opening-out " specular iron ore is described by Ibbotson[89], which he claims is more satisfactory than a fusion method. His description of the procedure is as follows :—" Pass the ore through a sieve of at least 90 mesh. Boil a weighed amount with strong hydrochloric acid and then dilute with some soft ashless paper which has been shaken to a pulp with water. Pour this mixture on to a pulp filter with constant agitation and wash. The filter, which is now uniformly grey owing to the thorough dissemination of the small crystals, is transferred to a crucible, dried, and then charred at the mouth of the muffle. The crystalline ferric oxide is reduced by the glowing mass of carbonised paper, and again re-oxidised when the paper is burnt off and the crucible more strongly heated. Everything now passes into solution on heating with hydrochloric acid, except a little silica."

An outline of methods of decomposition of miscellaneous materials for the determination of iron alone has been reported[84].

It is not proposed to describe the various methods of attack that have been put forward for the separation and determination of metallic iron, ferrous oxide and ferric oxide separately in iron-bearing materials. Reference

* Continued from p. 53 of the July issue

can, however, be made to the methods described by Lundell, Hoffman and Bright[85], Westwood and Mayer[86], Jones and Hedges[87], Morris[88], Ingeberg[92], Joseph, Scott and Kalina[93], Riott[94], Stengel[95], Wesly[96], Kitahara[97], Neumann and Meyer[98], H. U. von Vogel[99], and Chernyi and Podčenikova[100].

(*b*) *Manganese Ore*

A similar method of decomposition to that described above has been found satisfactory for the decomposition of manganese ore. Decomposition can be effected by attack with single or mixed acids (in which case a few drops of sulphurous acid or hydrogen peroxide may be added with advantage), or by fusion with potassium bisulphate or sodium carbonate. If manganese alone is to be determined, the ore may be dissolved by digestion with nitric acid and hydrogen peroxide. Any insoluble matter remaining after this treatment is filtered off, ignited, fused with potassium bisulphate, and the melt dissolved in dilute nitric acid and added to the main solution.

It should be noted that if decomposition of manganese ore or manganese-rich materials is carried out in platinum vessels, either by fusion of the material with sodium carbonate with subsequent solution of the melt in hydrochloric acid, or by direct attack on the ore with hydrochloric acid, there is a considerable attack on the platinum vessel due to the liberation of chlorine. The addition of a few drops of alcohol prior to the addition of the acid will overcome this difficulty.

A method for the analysis of pyrolusite (MnO_2) has been described by Primbsch[90].

(*c*) *Limestone, Lime*

There is no difficulty in decomposing these materials. If they are quite pure, they can be decomposed completely by treatment with hydrochloric acid. This is rarely the case with limestone, however, and a residue is usually obtained which may consist of quartz, clay and other silicates, carbonaceous matter, pyrites, etc., and which usually amounts to between 1 and 3%. When the insoluble residue is not to be analysed separately, it may in many cases be rendered soluble by ignition of the sample at 1,100°–1,200° C. for 10–15 minutes but this procedure fails if the proportions of soluble to insoluble substances are not suited to the formation of a cement. If this is the case, and the material is very impure and contains more than about 15% of silica and about 5% of ferric oxide and alumina, the finely powdered sample is thoroughly mixed with 0·5 to 1·0 g. of sodium carbonate and heated until the mixture is well sintered together. This procedure should be adopted for all siliceous limestones.

Methods for the decomposition of carbonate rocks are fully discussed by Hillebrand, Lundell, Bright and Hoffman[91].

(*d*) *Fluorspar*

Methods for the decomposition of fluorspar for chemical analysis depend upon the point of view for which the analysis is required. A complete analysis is rarely called for, or even attempted. Fluorspar is usually bought and sold on its calcium fluoride content, and the usual custom is to report the percentage of calcium fluoride as calculated from a determination of the calcium that remains after a preliminary treatment which removes the calcium that is not present as fluoride. From the point of view of steelworks practice, calcium fluoride, calcium carbonate, silica and total sulphur are the constituents usually determined.

A preliminary treatment of the finely ground sample, first with a hot acetic acid–bromine mixture, followed by a potassium bromide–bromine mixture and, finally, by an ammonium acetate solution, removes calcium carbonate, calcium sulphate, and any lead and zinc compounds present, and leaves silica and calcium fluoride insoluble. After filtration, the insoluble portion is used for the determination of silica by treatment with hydrofluoric acid, and the residue is used for the determination of calcium fluoride. In some cases it may be sufficient to treat the material with dilute acetic acid only, and to note the loss in weight, due regard being paid to the slight solubility of calcium fluoride under these conditions.

Fluorspar can be decomposed by fuming with either sulphuric or perchloric acid, the latter acid being preferable because the resulting products are easily soluble. It is advisable to make two or three evaporations with the acid to ensure that the fluorine is eliminated as completely as possible. Fluorspar can also be decomposed by fusing with potassium hydroxide, or by fusing with an alkali carbonate and an oxidising agent. A mixture of potassium carbonate and potassium nitrate is recommended on the grounds that the products of fusion are more easily soluble than when corresponding sodium salts are used.

If sulphur is to be determined, the sample is decomposed by fusion with potassium carbonate and potassium nitrate, and the fluorine eliminated by dissolving the melt in water, filtering, acidifying with hydrochloric acid and evaporating to dryness, repeating the latter process several times. Great care must be exercised in fusing the fluorspar. as the melts are very fluid and tend to " creep " over the top of the crucible.

In connection with the analysis of fluorspar, mention should be made of three excellent papers on the subject by Bidtel[101], Lundell and Hoffman[102] and Osborn[103], to which reference should be made for further information on this subject. Osborn's paper deals with the determination of some 12–15 minerals present in English fluorspars. Other papers relating to the analysis of fluorspar are those of Isubaki[104], who decomposes the material for the determination of fluorine by fusing the sample with an equal weight of titanium dioxide and a large amount of mixed sodium and potassium carbonates, and for the determination of silica by fusing with disodium hydrogen phosphate and mixed sodium and potassium carbonates; Winkler[105], who studied the factors affecting the decomposition of fluorspar by fusion with sodium and potassium carbonates; and Primbsch[106].

B—Iron- and Steelmaking Slags

Iron- and steelmaking slags are usually either acid or basic in character, depending upon the iron- or steelmaking process from which they are derived. There is a wide variation in the composition of the various steelmaking slags, even when they are obtained from the same steelmaking process, the difference very often being due to the different modes of practice employed by the steelmakers. Such a variety of complex alloy steels is now made in the electric furnace that slags derived from the making of such steels often contain varying amounts of the special alloying elements involved, and may demand special preliminary treatments. A knowledge, therefore, of the source from which a particular slag is derived is of great assistance to the analyst in choosing at the outset the correct method of decomposition to employ.

In spite of their great complexity, however, practically all iron- and steelmaking slags can be completely decomposed either by a direct attack with a mineral acid, or by a fusion with sodium carbonate, the procedure depending mainly on the ratio of silica to bases. Generally, as the proportion of silica increases, the resistance to attack by acids also increases.

Blast furnace slags, basic slags generally, and electric furnace reducing slags, can be successfully decomposed by treatment with hydrochloric acid. When decomposition with hydrochloric acid is carried out, the slag sample should first be boiled with a small quantity of water and the hydrochloric acid then added slowly in small portions at a time, boiling between additions, in order to prevent any coagulated silicic acid from enclosing particles of unattacked material, and so rendering them immune from further attack. If any undecomposed material remains, it must, of course, be collected, ignited, fused with a small amount of sodium carbonate, and the solution of the melt added to the main solution.

Acid open hearth slags, electric furnace oxidising slags, acid Bessemer slags and special slags, for example, those containing chromium, are best decomposed directly by a fusion with sodium carbonate. The subsequent treatment of the solution resulting from the decomposition or from the fusion will depend upon the analysis required.

If silica is not to be determined, slags may be decomposed by treating them with hydrochloric, nitric and hydrofluoric acids. Usually subsequent fuming with either sulphuric of perchloric acid is carried out in order to eliminate the fluorine. As previously stated, perchloric acid is, in general, preferable to sulphuric acid, particularly in the presence of much calcium.

With slags containing fluorine, the material should be decomposed by a fusion with an alkali carbonate (potassium carbonate is recommended here) if fluorine and silica are to be determined. For the determination of most of the other constituents of such slags, the sample may be decomposed by treatment with acids in the usual way, and the fluorine subsequently volatilised by fuming with sulphuric or perchloric acid, or rendered inert by the addition of boric acid. For the purpose of determining silica in slags containing fluorine, the sample may be decomposed by heating with 20% perchloric acid saturated with boric acid at 50° C., and finally fuming the solution for 5 minutes, according to the procedure described by Schrenk and Ode[106]. Good results using this method have been reported by Croall[3], who applied the methods to the determination of silica in basic electric furnace finishing slags containing fluorine. This method of decomposition is also recommended by Lamure[107] for the same purpose.

Chromium-bearing slags are best decomposed by a fusion with sodium peroxide in an iron crucible, if chromium alone is to be determined. For the determination of chromium in acid slags, Budaev and Shportenko[52] decomposed the sample by boiling with a mixture of 15 ml. of phosphoric acid, 85 ml. of dilute sulphuric acid (1 : 4) and 2–3 g. of pure calcium fluoride. After oxidising with nitric acid, the chromium was determined by the persulphate method.

Methods for decomposing titaniferous slags for the purpose of determining 3-valent titanium have been described by Chernomordik[108], and later modified by MacCardle and Scheffer[109]. In both cases the samples were treated with dilute sulphuric acid and a known amount of 5-valent vanadium and, in the method of MacCardle and Scheffer, some hydrofluoric acid. The excess of 5-valent vanadium is titrated with ferrous ammonium sulphate solution, using barium diphenylamine-sulphonate as indicator. As both 3-valent titanium and ferrous iron react with the vanadium, a correction must be made for the amount of ferrous iron present.

Barkov[110] decomposes slags for the determination of vanadium by heating a 0·5 g. sample of the slag with a mixture of 1 g. of magnesium oxide, 0·5 g. of sodium carbonate and 0·15 g. of potassium nitrate to about 1,000° C. in a current of oxygen. After dissolving the cooled melt in dilute sulphuric acid, the vanadium is determined by titration with ferrous sulphate and potassium permanganate.

In blast furnace and most basic slags, the greater part of the sulphur present exists as sulphide sulphur (calcium sulphide), which usually amounts to between 90 and 99% of the total sulphur, and the sulphate sulphur from 1 to 10%. A separate determination of the two forms is rarely called for, total sulphur being determined in nearly every case. For the determination of the sulphide sulphur[111], the slag sample is decomposed with hydrochloric acid in the presence of metallic zinc or tin. The hydrogen sulphide evolved is then determined as in the evolution method for steels. A variation of this is a procedure described by Quadrat[53], in which 1 g. of slag sample is mixed with 2 g. of zinc powder in a porcelain crucible, and the mixture covered with a layer of 1 g. of the zinc powder and heated for 7 minutes over a Teclu burner. After cooling, the mass is decomposed, in an apparatus as used for the determination of sulphur in steels, by dilute hydrochloric acid in a current of carbon dioxide ; the hydrogen sulphide formed is passed into a solution of cadmium acetate, and the sulphur determined iodometrically. The determination of sulphide sulphur in calcium silicate slags was also studied by Shaw[114].

For the determination of total sulphur in basic slags, it is recommended[112] that the sample, together with a small amount of sodium carbonate, should first of all be treated with bromine water, then with nitric acid, followed by hydrochloric acid, and the solution evaporated to fumes with perchloric acid. Treatment of the insoluble silicieous residue is advocated if the slag contains barium. Alternatively, the solution may be evaporated to dryness after the aqua regia treatment. Sulphate sulphur can be determined by decomposing the slag with hydrochloric acid, boiling to eliminate all the hydrogen sulphide, and then proceeding as above, or the sulphate sulphur may be taken as the difference between the total determined sulphur and the sulphide sulphur.

For the determination of sulphur in acid insoluble slags, these should be decomposed by fusing with an alkali carbonate and an oxidising agent (see Section 3B). Sodium carbonate and sodium nitrate are recommended for this purpose, and this process should preferably be carried out in an electric muffle furnace in order to prevent any contamination by sulphur compounds in the gases from burners.

Slags (and quite a number of other oxide-bearing materials) may be decomposed for the purpose of determining sulphur by heating the sample, mixed with a low-sulphur steel millings to act as an accelerator, and tin powder to serve as a flux, at 1,300°–1,400° C. in a stream of oxygen. The sulphur is evolved mainly as sulphur dioxide, together with a little sulphur trioxide, which are

absorbed in water and titrated with potassium iodide—potassium iodate solution.

Certain electric furnace finishing slags may contain carbide. By treating the slag with water, or a saturated solution of sodium chloride[115], acetylene is liberated, which may be collected and measured in a gas burette. Bogdanchenko[116] treated the sample with nitric acid saturated with sodium nitrate in a stream of oxygen, and passed the gases through a combustion furnace. The resulting carbon dioxide was absorbed and determined as usual.

Cupola slags are usually intermediate in composition between acid and basic steelmaking slags, and quite a large insoluble residue may remain after treatment with a mineral acid. If this is the case it is better to decompose the material initially by a fusion with sodium carbonate.

C—Refractory Materials

The methods for the decomposition of refractory materials for chemical analysis are as many and varied as the materials themselves, and no outstanding developments in this field of endeavour, except in one or two instances of a very specialised nature which will be mentioned later, have been recorded in recent years. Those procedures that have been published have usually related to a specialised method of decomposition for the determination of a particular element or constituent, for example, ferrous iron, and for rapid routine control purposes.

The methods for the decomposition of refractory materials will be considered under the three headings as indicated in Section 2C.

(*a*) *Acid Refractory Materials*

Acid solution methods of decomposition are usually applied to the higher grades of siliceous materials in this class of refractories. When applied to clays, firebrick, etc., a comparatively large insoluble residue usually remains which has to be further decomposed by fusion with a suitable flux.

Highly siliceous materials, such as sands, quartzites, silica bricks, etc., can be decomposed by heating with a mixture of hydrofluoric acid and either sulphuric or perchloric acids, if the silica is not to be determined directly. Alternatively the material may be decomposed by fusion with ammonium fluoride[117], and the residue either ignited or evaporated with sulphuric acid. These methods of attack have the advantage of removing silica readily and completely at the beginning of the analysis. The oxide residue remaining can be fused with a little sodium carbonate or potassium bisulphate, and the resulting solution of the melt can be utilised for the determination of ferric oxide, alumina, titania, calcium oxide, magnesium oxide, etc. Furthermore, these procedures provide a rapid routine check on the determination of silica by a direct loss in weight on the higher grade of silica refractories. It should be noted that quartz is much more resistant to attack by hydrofluoric acid than some other forms of silica or silicates, and that several evaporations with hydrofluoric acid may be necessary for the complete removal of silica. The material should be in a very fine state of division.

Fusion with sodium carbonate may be used as a general means of decomposition for all types of acid refractory materials, including the raw and fired products. Its use may be followed by the separation and determination of the usual oxide constituents.

According to Hoffman *et al*[127], kaolin can be decomposed by hydrochloric acid if the sample is first heated at about 700° C. for 15 minutes before treatment with the acid, when practically all the silica remains insoluble.

(*b*) *Basic Refractory Materials*

As stated in Section 2C, basic refractories cover a range of materials not all amenable to the same methods of decomposition. Each refractory type will, therefore, be considered separately.

The raw materials dolomite and magnesite can be decomposed in a manner similar to that described for limestone, paying particular attention to any small amount of undecomposed material. Dead-burned dolomite and magnesia are, however, more resistant to a direct acid attack with hydrochloric acid. Attack on the material is frequently very slow and incomplete, especially with a magnesite brick, and in such cases it is preferable to fuse the finely ground sample directly with sodium carbonate. According to Caley and Elving[118], burned magnesite (and presumably dolomite) can be decomposed by treating 1 g. of the sample contained in a Pyrex beaker, with 5 ml. of water and 10 ml. of perchloric acid (60%), heating on the steam bath until solvent action ceases, and then fuming off all the perchloric acid. The resulting residue can be dissolved in water, leaving the silica insoluble.

The decomposition of the other types of refractory materials which, for convenience, will be discussed here, namely the range of alumino-silicates and highly aluminous materials, is more difficult. This is particularly the case where the refractory has been prepared (as it should be) by burning at a high temperature. High alumina refractories, calcined aluminium oxide (corundum), etc., are not decomposed by an acid treatment in the ordinary way. They are decomposed, however, by heating with hydrochloric acid alone or mixed with an oxidising agent such as nitric acid, at 250°–300° C. in a sealed glass tube [4.83]. Calcined alumina may also be decomposed by fusion with potassium bisulphate. In this case it may be necessary to regenerate the flux to its original active state by the addition of sulphuric acid, if the fusion has been at all prolonged, as described in Section 3B. Bauxite can be almost completely decomposed by heating with a mixture of hydrofluoric, nitric and sulphuric acids[119]. A small undecomposed residue usually remains which can be filtered off, ignited, fused with potassium bisulphate and the melt dissolved in the main solution ; prolonged fusion with sodium carbonate will also decompose bauxite.

Sillimanite, mullite and related aluminium-silicate refractories, even when very finely ground, are only attacked to a slight extent by fusing them with sodium carbonate. They may, however, be decomposed satisfactorily by heating with a mixture of sodium carbonate and calcium oxide in the ratio of 6 to 1, respectively, at 1,200° C. for 30 minutes[120]. Pure alumina (cast alumina brick) was not completely decomposed by this treatment. The 200-mesh sample was only 80% decomposed, and 93% of the −325 mesh was completely fused. Another procedure was proposed by Barret and Schroeder[121], which involved a double fusion treatment (with intervening extraction and filtration), first with sodium carbonate and then with potassium bisulphate. This procedure is time-consuming and decomposition may not always be complete.

E. B. Read[122] used a flux consisting of equal parts of sodium carbonate and anhydrous sodium borate for

"opening-out" these materials, and a number of investigators have testified to the effectiveness of this flux. The proportions of the constituents of the flux may be altered without decreasing to any great extent its efficiency. The whole range of aluminous refractory materials from pure alumina to fireclays may be satisfactorily decomposed by this procedure, and it appears to be the best method so far proposed for decomposing these types of materials. Hazel[31], in discussing the decomposition of refractory silicates, considers that the mixture of equal parts of sodium carbonate and sodium borate approaches an almost universal flux, and states that even samples as coarse as 24-mesh can be decomposed in about 20 minutes. The decomposition of aluminous materials and silicates has been discussed in a valuable paper by Ellison[123].

(c) *Neutral Refractories*

Methods for decomposing high alumina materials for the determination of the alkali metals have already been discussed in Section 3C (b).

Zirconium refractories, which will also be considered in this section, are not normally used in iron and steelworks practice. Zircon ($ZrO_2 \cdot SiO_2$) has been used, however, as an addition to magnesite bricks to improve their shock resistance, and as an addition to magnesite for basic high-frequency furnace linings. According to Chesters[124], steel pouring nozzles made from zircon have given promising results. The chief constituents of zirconium refractory materials are the crude or refined oxide (Zirconia–ZrO_2) and zirconium silicate (Zircon–$ZrO_2 \cdot SiO_2$), and when used as refractory materials they are usually mixed with some kind of bonding material. Methods for the decomposition of these materials, therefore, are primarily methods for the decomposition of zirconia and zircon.

In the following discussion the terms "zirconium" and "zirconia" refer to mixtures of zirconium and hafnium and zirconia and hafnia respectively, in the proportions in which they are usually found associated together in nature, The behaviour of hafnium is, for all practical purposes, identical with that of zirconium.

The application of some of the methods of decomposition already described in Section 3 will be discussed in detail for the "opening-out" of zirconium refractories, as typical examples of the manner in which they can be applied to the decomposition of a highly refractory material.

Zirconia and zircon are inert to the action of all acids except hydrofluoric acid, and so the decomposition is always effected by the use of fluxes. Among the many fluxes that have been proposed are alkali carbonates, alkali hydroxides, alkali fluorides, borax, alkali bisulphates and sodium peroxide. The use of sodium carbonate alone is not very satisfactory, as decomposition is usually incomplete.

Decomposition by fusion with sodium peroxide was recommended by Travers[125]. Three ways of carrying out this procedure will be described.

The sodium peroxide—carbon fusion method of Muehlberg[16], later modified by Marvin and Schumb[17], is simple and easy to carry out. It can be operated in the following manner. In a 50 ml. nickel crucible is placed about 2·5 g. of an intimate mixture (made by gently rolling together the two constituents in a large dry bottle) of 15 parts of sodium peroxide with 1 part of 100 mesh pure sugar carbon. 1 g. of the finely ground sample is placed upon this mixture, then covered with more fusion mixture and intimately mixed at the surface. A layer of the fusion mixture is used as a cover, and the crucible is immersed in cold running water to a level slightly above that of the contents of the crucible. The ignition is started by means of the glowing tip of a cotton thread, and the crucible is immediately covered. After fusion is complete and the crucible is cold, the crucible and cover are transferred to a beaker, the melt leached with water and gently heated. After removing and washing the cover and crucible, the solution is acidified with hydrochloric acid. If any undecomposed material is evident, it is filtered off, ignited, and the fusion and extraction repeated, using appropriately smaller quantities of flux.

The sodium peroxide fusion may also be carried out by fusing the material in a nickel crucible previously lined with a layer of fused sodium carbonate. The function of the sodium carbonate lining is merely to prevent any appreciable amount of nickel from going into solution. Only sufficient heat should be used to melt the sodium peroxide and maintain it in a fluid condition, without melting the sodium carbonate.

The third method of carrying out this decomposition is by sintering with the sodium peroxide in a platinum crucible under strictly controlled conditions, as described by Seelye and Rafter[14] and by Rafter[15]. The procedure is as follows. Transfer 0·2–1·0 g. of the sample (ground to pass a No. 240 B.S. sieve) to a 30 ml. platinum crucible, and mix with 1·2–3·0 g. of sodium peroxide. Cover the crucible and place it on a Vitreosil plate, well inside an electric muffle furnace and near to a pyrometer, the point of which rests on the plate immediately next to the crucible : leave for exactly 7 minutes. Keep the temperature at 480° ± 10° C. for the final 5 mins. After disintegration of the cake with water, the extract is acidified with nitric acid (which should be added rapidly to the cold alkaline solution to avoid the precipitation of insoluble acids, which tends to occur if the neutral point is approached slowly), and the solution filtered. Any unattacked material can then be recovered and re-treated. It is claimed that 99–100% decomposition can be accomplished at the first attempt.

Fusion with borax was strongly recommended by Lundell and Knowles[126] for the decomposition of all zirconium minerals, and the following procedure is recommended. Four grams of the flux are melted in a platinum crucible and allowed to cool. About 0·3 g. of finely ground sample is placed on the top of the fused borax, the crucible is covered and heated at a temperature sufficient to maintain a fluid melt until thorough fusion has taken place and the melt is clear, which does not normally require more than 30–45 minutes. During the fusion it is recommended that the rather viscous melt be stirred occasionally with a small platinum rod or stiff wire, which is allowed to remain in the crucible. The cooled melt is extracted in 150 ml. of dilute hydrochloric acid (1 : 5).

It is pointed out that this flux is particularly suited to the decomposition of samples in which only zirconium is to be determined, by precipitation with cupferron, since boric acid does not interfere with the use of this reagent. If other elements such as aluminium calcium, magnesium, etc., present in the sample are to be determined, the boric acid must be removed by volatilisation as methyl borate in the usual manner.

According to Moore *et al*[128], zircon can be completely decomposed by heating the finely ground material with

a mixture of sodium hydroxide (3 parts) and sodium peroxide (1 part), in a nickel vessel. A clear and complete fusion is said to result in about 20 minutes. Subsequent treatment of the melt will depend upon the analysis in view. According to Axt[130], zircon sand can be decomposed by fusing with sodium hydroxide at 600° C.

Decomposition by the use of potassium hydrogen fluoride was applied by Smith and James[129], in the following manner. The finely ground material is fused with 12–15 times its weight of potassium hydrogen fluoride in a platinum vessel, first over a small flame, then gradually raising the temperature until the mass just fuses to a clear liquid, and no longer. If the fusion is carried out up to this point, there is no loss of zirconium by volatilisation, but continued heating after a clear fusion is obtained may cause a small loss. The cooled melt is treated with 15 ml. of dilute sulphuric acid (1 : 1), evaporated to fumes of sulphuric acid, cooled and the mass dissolved in water. Silica, of course, cannot be determined after this treatment.

Powell and Schoeller[131] decompose materials high in zirconia by fusion with sodium carbonate, followed by a bisulphate fusion of the residue from the carbonate fusion. If the material is ferruginous, they recommend that it should be first extracted with strong hydrochloric acid before fusing it with sodium carbonate. Their procedure is as follows. 0·25 g. of the material (if ferruginous) is digested with 10 ml. of concentrated hydrochloric acid. The solution is evaporated to dryness, the residue extracted with 25 ml. of hot normal hydrochloric acid, and the insoluble portion collected, washed and ignited in a platinum crucible. The filtrate is reserved.

The ignited insoluble residue from the above operation, or the weighed material if non-ferruginous, is fused with 5 g. of sodium carbonate over a high temperature burner for 1 hour. The cold melt is disintegrated with boiling water, and the insoluble residue is collected, washed once with a 2% solution of sodium carbonate and twice with water, ignited and fused with 4 g. of potassium bisulphate (it would be better to use the sodium salt here owing to the greater solubility of the double sodium—zirconium sulphates) in a silica crucible and the melt dissolved in 5% sulphuric acid. This solution is added to the reserved filtrates from the above operations, and everything should be in solution except silica.

According to Hillebrand, Lundell, Bright and Hoffman[132], baddeleyite (ZrO_2) can be decomposed by fusion with potassium pyrosulphate, but zircon (ZrO_2SiO_2) is only slowly attacked by this treatment.

There is thus, a wide choice in the fluxes that may be used for decomposing materials rich in zirconium. A flux should be used, however, that is compatible with the analytical operations that are to follow its use.

(*c*) *Neutral Refractory Materials*

Among this class of materials, the chrome refractories are the most important, both commercially and from the metallurgical point of view, and satisfactory methods for their decomposition are of prime importance. While the straight chrome refractories find but little application today, the chrome-magnesite refractories are widely used in the steel industry. Other composite refractories containing chromium, such as chrome-silica, chrome-alumina, chrome-dolomite, chrome-olivine, etc. have been developed, but they will not be considered separately. They can be decomposed for chemical analysis by the methods about to be described for chromite and chrome-magnesite. A large number of methods have been used for the decomposition of chromite and chrome-magnesite refractories, the method of attack depending upon the requirements of the analysis, but many of these methods have been discarded for one reason or another.

Among the acid decomposition methods that have been proposed for chromites are direct solution of the material in 70% perchloric acid[133], in a mixture of sulphuric and perchloric acids[134], or in a mixture of sulphuric, phosphoric and perchloric acids[135]. For the determination of iron alone, the material may be decomposed by treatment with hydrochloric and nitric acids, and subsequently fuming with perchloric acid, the chromium being practically entirely eliminated by continued treatment with hydrochloric acid followed by evaporation to fuming until no further evolution of chromyl chloride occurs. If any small insoluble residue remains, it is filtered off, fused with sodium bisulphate and the melt dissolved in the main solution. According to Caesar and Konopicky[136], concentrated phosphoric acid dissolves chromite and chromic oxide on heating. If some vanadium pentoxide is also present, this method of attack is suitable for determining the ferrous oxide content of the material.

There is a wide choice of fluxes that may be used for this class of materials. Fusion with sodium peroxide is quite satisfactory, and is the method most commonly employed. If chromium is to be determined, an iron or porcelain crucible may be used. For the determination of the other constituents, sintering with sodium peroxide, in a platinum or nickel crucible, as described in Section 3B, is a most attractive procedure ; 98% decomposition in one operation is claimed[15] when this method is used. Less desirable methods are decomposition by fusion with a mixture of sodium carbonate and potassium nitrate, or sintering with a calcium oxide-sodium carbonate mixture, in that invariably decomposition is not complete, and a residue is left that requires further treatment. A satisfactory decomposition of chrome ore, especially if it contains quartz, can be obtained by a fusion with a mixture of 5 g. of sodium carbonate and 2 g. of anhydrous borax per 0·5 g. of sample[137]. Theobald[138] strongly recommends a fusion of the material with a mixture of equal parts by weight of sodium hydroxide and sodium peroxide, a procedure for which he claims a number of advantages.

Chromite and chrome-magnesite brick, can also be "opened-out" for chemical analysis by a fusion with potassium pyrosulphate[139,142]. For success with this method, the material must be in a very fine state of division, and the fusion should be carried out in a silica crucible as the process may be prolonged. If necessary the flux may be regenerated by allowing the melt to cool, adding a few drops of concentrated sulphuric acid, and again heating, as already described. It is the author's opinion that sodium pyrosulphate is a better flux than the potassium salt for decomposition of chromite refractories. The double sodium-chromium sulphates formed are more soluble that the double potassium salts, and the sodium salts give less trouble in subsequent operations.

Applications of some of these methods of decomposition to the complete analysis of chromite and chrome refractory materials are described by Van der Walt[139,142] by Cunningham and McNeil[137], and by Boyle, Musser and Keim[143].

5—CONCLUSION

This paper is based on a report[144] prepared by the author for the Blast Furnace Raw Materials and Slags, Steelmaking Slags and Refractories Analysis Sub-Committee, British Iron and Steel Research Association, the present constitution of which is given in Appendix I. During the course of the Committee's work on the determination of iron in oxide-bearing materials, the results obtained for iron reflected the methods of decomposition employed for these various materials, so much so that it was decided to survey and study the various chemical methods of decomposition that were available for such miscellaneous substances. The methods of decomposition used by the members of this Sub-Committee in their work on the determination of iron are given in Appendix II.

The author acknowledges with thanks the permission given by the Methods of Analysis Committee of the British Iron and Steel Research Association, (Chairman—Dr. E. Gregory), for this report to be published.

APPENDIX I.

Constitution of the Sub-Committee

The present constitution of the Blast Furnace Raw Materials and Slags, Steelmaking Slags and Refractories Analysis Sub-Committee (as at 24th March, 1955) is Mr. D. Manterfield (Chairman), Steel, Peech and Tozer; Mr. B. Bagshawe, Brown-Firth Research Laboratories; Mr. W. F. Charteris, Colvilles, Ltd.; Mr. E. W. Harpham, Richard Thomas and Baldwins, Ltd.; Dr. T. S. Harrison, Appeleby-Frodingham Steel Co., Ltd.; Mr. A. P. Lunt, Parkgate Iron and Steel Co., Ltd.; Mr. G. Padget, United Steel Cos., Ltd.; Mr. A. W. Reed, Consett Iron Co., Ltd.; Mr. N. D. Ridsdale Bureau of Analysed Samples, Ltd.; Mr. C. W. Short, John Lysaght, Ltd.; Mr. G. P. Storer, Stanton Iron Works Co., Ltd.; and Mr. T. H. Williams, Stewarts and Lloyds, Ltd,

APPENDIX II.

Methods of Decomposition

(1) *Hydrochloric Acid Decomposition*

0·5 g. of sample is placed in a suitable reaction vessel together with 25 ml. of hydrochloric acid (sp.gr. 1·16) and the mixture is digested (Note 1). 5 ml. of nitric acid (sp.gr. 1·42) (Note 2) is added and, if necessary to assist complete decomposition, 1–2 ml. of hydrofluoric acid (Note 3). Digestion is continued, without allowing undue evaporation, for a convenient period or until solution is complete. The solution is then filtered, the paper well washed with hot hydrochloric acid (1 : 19) and treated as (*a*) or (*b*) below.

(*a*) Calcine the paper and residue in a platinum crucible, add 1–2 ml. of hydrofluoric acid, 1 ml. of sulphuric acid (sp.gr. 1·84), and warm until fumes of sulphur trioxide are evolved. Cool, dilute and add to the main solution (Note 3).

(*b*) Calcine the paper and residue in a porcelain crucible, fuse with a minimum qnantity of potassium bisulphate, cool, extract and add to the main solution.

At this stage the solution may be fumed with 5 ml. of sulphuric acid (sp.gr. 1·84), if desired, failing which, any interference effects of hydrofluoric acid may be overcome by adding boric acid.

Note 1. When solution can be assisted by the use of a reducing agent, sulphurous acid or stannous chloride may be added. Omission of the oxidising treatment may then be advantageous.

Note 2. Alternatively, oxidation may be carried out by adding 0·1 g. of potassium chlorate.

Note 3. This modification cannot be applied when the determination of silica is required.

(2) *Sodium Carbonate Fusion*

Mix 1 g. of dried sample (72 B.S. mesh) with 6 g. of sodium carbonate in a 40 ml. platinum crucible. Cover, fuse gently at 900° C. for 10 minutes, and then at 1,000° C. for half an hour. Cool, place the crucible and contents in an evaporating dish (20 cm. diameter), cover, and add a mixture of 100 ml. of water, 8 ml. of hydrochloric acid (sp.gr. 1·16), and 20 ml. of saturated sulphurous acid solution. Warm until the fused cake has disintegrated and effervescence ceases, remove the clean crucible and lid. Bring the contents of the covered evaporating basin to boiling point for 2 minutes. Take off the boil, rinse the cover, and evaporate the contents of the uncovered basin for silica, etc.

(3) *Sodium Peroxide Fusion* (for chrome bricks)

Mix 0·5 or 1·0 g. of dried sample (100 B.S. mesh) with 5–8 g. of sodium peroxide in a 75 ml. nickel crucible, using a nickel spatula. Heat the covered crucible at 500° C. for 10 minutes, and then heat the uncovered crucible to complete fusion at a dull red heat over a Meker burner, using a pair of bowed tongs. Whilst heating, gently swirl the contents of the crucible and observe when the attack is finished, which is usually in about 5 minutes. Replace the lid and allow to cool. Place approximately 0·5 g. of sodium peroxide on the underside of the lid and heat over a Meker burner with gentle swirling to attack any undecomposed sample. Allow to solidify and replace the lid on the crucible to cool.

Place the crucible and lid in a 600 ml. beaker and add 200 ml. of warm water. After extraction, remove the crucible and lid and rinse with hot water into the beaker. The crucible and lid are swilled with either hydrochloric acid (sp.gr. 1·16) or sulphuric acid (1 : 4) according to the purpose of the analysis, and the contents of the beaker suitably acidified and brought into solution.

(4) *Potassium Bisulphate Fusion*

Heat a suitable quantity of potassium bisulphate in a platinum dish (80 ml.) until the fusion commences to give off fumes of sulphur trioxide. Pour out on to a platinum lid to cool. The fused cake is broken into approximately half-gram pieces, bottled, and labelled potassium pyrosulphate.

Melt 5 g. of the potassium pyrosulphate in a platinum dish (80 ml.). Allow to cool. Place 0·5 g. of dried sample on the surface. Put on the lid and heat gently until the pyrosulphate melts and the sample is diffused throughout the molten mass. Remove the lid. Hold the dish by means of platinum tipped tongs and continue heating with gentle swirling until attack is complete. If the fusion is overheated and solidifies through loss of sulphur trioxide, it may be regenerated by allowing to cool and adding 1 ml. of sulphuric acid (sp.gr. 1·84) and then reheating very cautiously until the contents of the dish again become uniform.

The underside of the platinum lid can be cleaned, if necessary, by fusing on it about 0·5 g. of potassium pyrosulphate and, by gentle movement, allowing the fused melt to flow over the surface. The fusion is ex-

tracted with dilute sulphuric acid (1 : 9) and, if necessary, the solution is evaporated to fumes for the removal of silica.

(5) *Sulphuric Acid Decomposition*

0·5 g. of sample in a suitable reaction vessel is treated with 50 ml. of dilute sulphuric acid (1 : 9), solution being assisted if necessary by additions of nitric and/or hydrofluoric acids. The solution is taken to fumes, diluted and filtered, the paper being washed with hot dilute sulphuric acid (1 : 49). The paper and residue are calcined in a porcelain or silica crucible, fused with a minimum quantity of potassium bisulphate, extracted, and added to the main solution.

(6) *Perchloric Acid Treatment*

Treat 0·5 g. of finely divided sample with 15 ml. of hydrochloric acid (sp.gr. 1·16) and 5 ml. of nitric acid (sp.gr. 1·42), and digest at boiling point for 10 minutes. Cool, add 20 ml. of perchloric acid (sp.gr. 1·54) and evaporate to fumes. Fume strongly for 5 minutes with the beaker covered by a watch glass (Notes 1 and 2). Cool, dilute with water, filter and if necessary treat the insoluble residue by fusion with sodium bisulphate.

Note 1. If chromium is to be removed, allow the fumed solution to cool slightly, treat with a few drops of hydrochloric acid and again fume. Repeat the addition of drops of hydrochloric, followed by fuming, until no further evolution of chromyl chloride occurs.

Note 2. The decomposition is sometimes assisted by the presence of 5–10 ml. of sulphuric acid (sp.gr. 1·84) in the initial solvent. This modification is not of general application, and should not be used in the presence of large amounts of barium or calcium.

(7) *Sodium Peroxide Fusion* (in a lined crucible)

Weigh 15 g. of anhydrous sodium carbonate into a clean platinum crucible (suggested size : capacity 60–70 ml., diameter 6–7 cm.). Place in a muffle furnace (temperature 900° C.) and allow the carbonate to flux. Remove the crucible from the furnace and, at the same time, gently swirl the crucible so as to form an even lining of sodium carbonate extending to about 1 in. up the walls of the crucible. Allow to cool. Add 8–10 g. of sodium peroxide and 1 g. of sample, and mix together with a glass rod. Heat at the front of the muffle until the mass shows signs of fusion. The crucible should be supported in the muffle on a pipeclay triangle, to allow the sodium peroxide to fuse without fusing the lining.

Allow the sodium peroxide to remain fused at 650° C. for 2–3 minutes and then cool. Extract with water at about 20° C., and wash into a 600 ml. squat beaker (Note : if the water is too warm, the reaction becomes violent, but if the water is too cold, the reaction is rather slow). When the extraction is complete, boil well, allow to settle, filter through a filter paper of strong texture, and wash well with hot water. This removes the bulk of the fusion salts, aluminium and chromium.

Dissolve the residue from the paper with 100 ml. of dilute sulphuric acid (1 : 9) into a 600 ml. wide mouth conical beaker. Rinse the platinum crucible with a few drops of hydrochloric acid (sp.gr. 1·16), take to fumes of sulphuric acid, cool, dilute and add to the main acid solution. Proceed with the analysis as required.

(8) *Calcium Oxide-Sodium Carbonate Sinter*

Sinter Mixture :—

Calcium Oxide	—4 parts by weight.
Sodium Carbonate	—1 part by weight.

Transfer 1 g. of sample to a platinum dish. Add 5 g. of sinter mixture and mix thoroughly. Heat for 10 minutes at 850° C. Transfer to a muffle at 1,200° C. for 30 minutes Extract the sintered product, which should be acid soluble and continue according to the needs of the analysis. Some types of chrome refractory may have small insoluble residues from this treatment, and a further fusion with potassium bisulphate may be necessary.

(9) *Sodium Carbonate-Sodium Borate Sinter*

Sinter Mixture :—

Sodium Carbonate (anhydrous)	—5 parts by weight.
Sodium Tetraborate (anhydrous)	—1 part by weight.

Transfer 1 g. of sample to a platinum dish. Add 2 g. of sinter mixture and mix thoroughly. Heat for 10 minutes at 850° C., and transfer to a muffle at 1,200° C. for 30 minutes. Extract, etc., as in Method 8 above.

(10) *Magnesium Oxide—Sodium Carbonate—Potassium Carbonate Sinter.*

Sinter mixture :—

Calcined Light Magnesia (MgO)	—4 parts by weight.
Sodium Carbonate (anhydrous)	—1 part by weight.
Potassium Carbonate (anhydrous)	—1 part by weight.

Procedure as in Method 8 above.

(11) *Borax Fusion* (for highly aluminous materials).

Mix 1 g. of dried sample with 5 g. of dried borax in a 40 ml. platinum crucible. Cover the crucible and heat gradually to a temperature of 1,000° C., maintaining this temperature for half an hour. Cool, extract the melt with 150 ml. boiling water in a 500 ml. covered beaker. Add 50% v/v sulphuric acid until acid, adding 10 ml. excess. Remove the clean crucible and lid, washing both with hot water.

Borax fusions have a limited field for attaining complete solution, but fusions using a mixture of 2 parts of sodium carbonate and 1 part of sodium borate have been more successful than sodium borate alone.

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Steelworks Analysis by Quantometer

Pioneer Venture by Steel, Peech & Tozer

ALTHOUGH it is in the aluminium industry that the Quantometer—a direct reading instrument for spectrographic analysis—has found its widest application to date in this country, it is also making headway in other fields. The rapidity with which accurate results can be attained make it an ideal means of routine control where metals are being melted, refined or alloyed, and the first Quantometer to be installed in a British steelworks—the Steel, Peech & Tozer Branch of the United Steel Companies—is now working nearly 24 hours a day on production checks in steelmaking. Although standardised components are used in its construction, each instrument is designed, adjusted and calibrated to satisfy the particular analytical requirements of the industry or laboratory concerned. The Steel, Peech & Tozer installation covers the analysis of plain carbon steels for residual elements, alloy steels of the nickel, chromium, molybdenum type, blast furnace sinters, and varying types of steelmaking slags. The selected constituents for analysis are phosphorus, silicon, manganese, nickel, chromium, tin, copper, molybdenum, aluminium, vanadium, titanium, lead and boron in steels, and silica, iron, lime, phosphorus pentoxide, manganese oxide, magnesia, alumina and fluorine in slags or sinters.

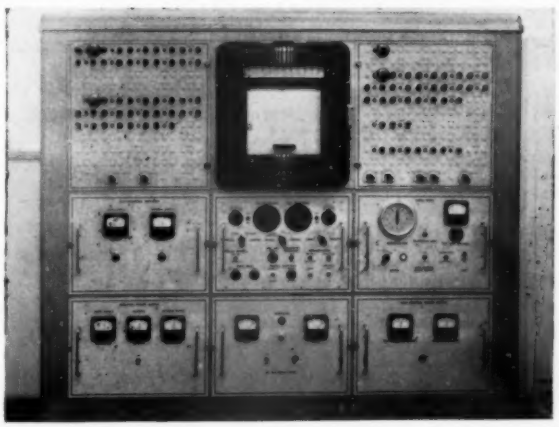
Description of Instrument

The Quantometer, which was supplied by the European branch in Lausanne, Switzerland, of Applied Research Laboratories, Glendale, California, consists of three units:—

(*a*) The source unit, which supplies power to the spark gap. Provision is available for varying the electrical parameters of the discharge to give "spark-like" and "arc-like" excitation.

(*b*) The spectrometer, which consists of a 1·5 meter grating instrument in which the Rowland circle is mounted vertically. This covers a spectrum range of 2,000–7,000 Å. with a dispersion of 6·95 Å/mm. in the first order, and 3·5 Å/mm. in the second order, using a grating ruled 24,400 lines to the inch. Also included in this unit are the slit frames, mirrors and multiplier phototubes.

(*c*) The recording console, which contains the measuring circuits, power supplies, attenuators controlling the phototube sensitivities, automatic timers and switching mechanisms. It controls the sequence of operation in the various steps of analysis. A Leeds and Northrup Speedomax recorder is incorporated, which registers each element of a group in sequence at 2·6 second intervals.



The recording console of the instrument.

In addition to the foregoing, a power supply to the source unit is provided by a Schindler motor-generator set to ensure stability of voltage and frequency of the supply. A Zenith stabiliser on the mains is also available in case of emergency.

The whole installation is housed in a separate room with special air conditioning equipment supplied and installed by the Pressed Steel Co., Ltd. The temperature is maintained at 70 ± 2° F., and the relative humidity at 50 ± 5%.

Principle of Operation

The sample under analysis is excited, using the sample itself as the electrode with a counter electrode of pure graphite. A measured gap of 3 mm., a pre-integration time of 5 seconds, and an integration time of 20 seconds are normal conditions. Pre-selected lines in the resultant spectrum are isolated by the respective slits and focussed by mirrors on to multiplier phototubes. The photocurrents in each case charge a condenser with a very high dielectric resistance. Included is a selected iron line which serves as an internal standard. The rise of voltage of this standard iron line is traced as the exposure proceeds. At full scale deflection, the exposure is automatically terminated; simultaneously, the charging of all condensers ceases and a stepping switch selects the

remaining condensers in sequence, recording the charge on each as a step on the chart, the height of which represents the concentration ratio of each element concerned.

The instrument is pre-calibrated by an adequate series of homogeneous and accurately analysed standard samples covering the ranges of concentration desired. These are carried through in the normal manner and working curves are prepared relating recorder readings to percentage concentration.

Application to Production

The Quantometer is essentially a production control instrument. It is important to provide technical control of steelmaking at all stages of manufacture and processing. The more rapidly an accurate analysis is produced on bath samples during refining, the more efficient is the control. Economies can be effected in the consumption of alloying elements due to the ease with which analyses can be made immediately prior to making the necessary additions. Furthermore, it will undoubtedly assist the production rate. A research programme was planned and has been partially completed prior to putting the instrument into everyday use. It is now in production use for most of the 24 hours, giving very satisfactory results.

A sample is taken from each charge at the melt and despatched to the laboratory by pneumatic tube. On receipt, the sample is prepared by grinding on a horizontal grinder and finishing on a band facer. It is analysed for the necessary elements and the results despatched back to the melting shops by a small electronic instrument which reproduces a facsimile of a written message at the receiving end.

Transit of the sample to the laboratory takes about 4 minutes, sample preparation 2 minutes, the actual analysis 1 minute and despatch of the result less than 2 minutes. The time occupied for the complete exercise is, therefore, about 9 minutes.

Accuracy

As a photometric device, using a constant light source, the instrument has been shown to have a reproducibility of better than 0·2%. In routine use for residual elements up to 0·5%, the accuracy is better than 5% of the concentration. For low alloy steels up to 5% concentration, the accuracy is better than 2·5%.

In the research programme on highly alloyed steels, the accuracy was better than 1% of element concentration. It will be seen, therefore, that the instrument compares very favourably with precision wet chemical analysis.

Exhibits of Metallurgical Interest at the Physical Society Exhibition

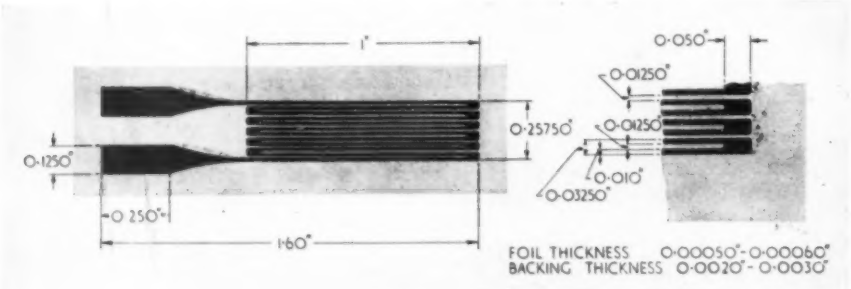
The exhibits at the Physical Society's annual exhibition of scientific instruments usually include a number of interest to workers in the metallurgical field. This year was no exception and in this issue we continue a short series of reviews in which such items will be described.

Foil Strain Gauges

THE foil strain gauges shown by the Electronics Division of Saunders-Roe, Ltd., owe their development to failures encountered with the use of wire strain gauges in work on helicopters. A high proportion of the failures of the wire gauges was due to the vulnerability of the attachments of the gauge winding filaments to the lead-out wires. There are also difficulties in waterproofing gauges for underwater applications in the development of flying boats.

As a result of these experiences, a foil type gauge, which is claimed to be superior to the conventional wire paper gauge, has been developed. The gauges are manufactured by Technograph Printed Circuits, Ltd., who use a technique in which the required gauge pattern is laid down on the surface of metal foil in an acid-resisting ink and the surplus metal removed in an etching bath. Copper-nickel foil of 0·0005 in. thickness is used, bonded to a thin backing film of epoxy-ethylene. The total thickness of 0·003–0·0035 in. is only half that of a comparable wire gauge. The gauge factor is approximately 2·0 and its resistance value is centred at 55 ohms.

A typical grid pattern consists of twelve parallel "ribbons" connected in series and terminating in two connecting tags which are enlarged at the ends to prevent fracture of the grid connections. In addition, by increasing the width of the grid reversing points, the cross-sensitivity is reduced to a minimum, and firm



Dimensional details of Saunders-Roe foil strain gauge

attachments are provided for the grid foil. Furthermore, the effective gauge length is clearly defined and the lag in the transmission of shear from the specimen to the surface of the gauge element is minimised.

The outstanding advantage of this method of strain gauge manufacture is that, due to the rectangular cross-section of the elements, very high input currents may be used with stability. It is therefore possible to drive robust meters and recording galvanometers directly, with consequent simplification of instrumentation.

For strain gauging torsion members and diaphragms, alternative two-dimensional grid patterns suitable for the purpose have been designed.

Electro-Titration Apparatus

Originally designed for the analysis of steels, the new electro-titration apparatus shown by Cambridge Instrument Co., Ltd., can be used wherever volumetric analyses are used, as it simplifies the problem of determining "end points" in coloured solutions. The apparatus has been completely re-designed and improvements include the introduction of a magnetic stirrer which allows the motor to be placed beneath the platform, where it is better protected and does not obstruct the use of the electrodes and burettes.

The motor rotates, through a friction drive, a magnet situated underneath the beaker of solution, and the rotating magnetic field causes a suitably coated magnet, placed in the solution, to be likewise rotated, thus providing efficient stirring. Two types of magnet are provided, one covered with polythene which is less liable to cause breakage, the other glass-covered for use where strong solutions or hot liquids might damage the polythene covering. The titration apparatus is provided with a switch and speed control for the motor so that small quantities of liquid can be efficiently agitated without splash.

Cambridge electro-titration apparatus

With the improved re-arrangement of the electrodes ordinary straight burettes can be used, and these together with the electrodes can be raised away from the beaker by the simple operation of a lever.

International Kilogramme Weight for South Africa

L. Oertling, Ltd., have just completed an order for the South African Government which involved the manufacture of an international standard 1 kilogramme weight having an exceptional degree of accuracy. This weight has been manufactured to a very stringent specification which included a tolerance of only 0·15 mg. on the finished mass. The weight was made from an alloy containing 90% platinum and 10% iridium, supplied by Johnson Matthey, Ltd., of Hatton Garden, and is in the form of a cylinder of equal diameter and depth with a slightly concave base so that the weight rests on an annular ring.

This weight, which becomes one of the world's international kilogrammes, was certified by the International Bureau of Weights and Measures, at Sevres, near Paris, and was shown to be well within the permitted tolerance. Its production involved a weighing accuracy of two parts in 100 million, and it is probable that weighing to this degree of accuracy has not previous been carried out as part of a commercial undertaking. Greater accuracy is of course obtainable, but always in laboratories devoted entirely to the accurate measurement of mass. In fact, it is doubtful whether measurement of this accuracy in any field is normally part of a manufacturing process. The manufacture of this standard weight has involved a protracted series of accurate weighings coupled with the removal of successively smaller and smaller amounts of material from the weight, so that the correct nominal mass and the optimum surface finish were achieved simultaneously.

It may be recalled that Oertling completed last year the manufacture of a primary standard 10 Tola Weight for Pakistan, and the completion of the South African international kilogramme so shortly afterwards is a notable achievement which reflects credit not only on the actual manufacturers, but on the whole of the British instrument industry.

Basic Slag Standards

Bureau of Analysed Samples, Ltd., Newham Hall, Middlesbrough, announce the issue of a series of basic slag samples specially standardised for sulphur by the method of analysis published in B.S.1121 : Part 29 : 1953. The sulphur contents are as follows :—

B.C.S. No. 174	0·16%
B.C.S. No. 249	0·29%
B.C.S. No. 248	0·42%

These samples have been specially prepared for obtaining the empirical factor necessary when determining the sulphur in basic slags by the rapid combustion process in connection with slag control in the basic open hearth process. The analyses were made by the members of the Raw Materials, Slags and Refractories Analysis Sub-Committee of the British Iron and Steel Research Association.

The slags are packed in bottles containing 25 g. of each sample, and may be obtained direct from the Bureau or through any of the recognised laboratory furnishers.

Experimental Steelmaking and Rolling Facilities at Swinden Laboratories

IT is inevitable that the research and development department of a company should itself always be in the course of development. One expects, therefore to hear of increased facilities becoming available at such research establishments as Swinden Laboratories at Rotherham—the Research and Development Department of the United Steel Cos., Ltd., erected at a cost of £250,000 and officially opened in 1952—where recent additions to the engineering and metallurgical equipment include new electric steelmaking furnaces and an 11-in. 3-high experimental hot rolling mill.

Steelmaking Units

The furnace plant, installed by Electric Furnace Co., Ltd., comprises three high frequency electric steel melting units capable of producing experimental ingots of 5, 25 and 112 lb. weight, respectively. High frequency power is supplied to the furnaces from a motor alternator of Electric Construction Co. manufacture, with an output of 50 kW. at 9,900 cycles single phase, driven by a 96 h.p. motor running at 3,000 r.p.m. on a 415-volt 3-phase 50-cycle supply.

Experimental Rolling Mill

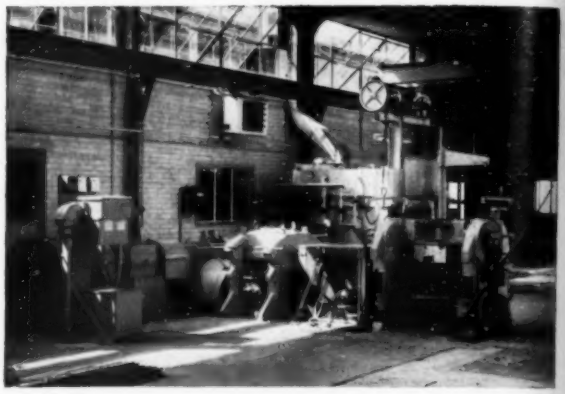
The rolling mill is situated in the same building, adjacent to the furnaces, and was supplied by B. Thornton, Ltd., It is driven by a Metropolitan-Vickers 100 h.p. A.C. motor through a David Brown 4-speed gearbox, Radicon worm reduction gear, and pinions. The mill is served by an electric direct resistance billet heater designed and constructed by the research department's staff, and by a 4 ft. square hearth gas-fired muffle furnace of Thermic design.

Three main functions are expected to be fulfilled by the experimental mill :—

(1) To roll ingots from the high frequency furnaces into bars, from which specimens can be made for metallurgical examination and mechanical testing, in the development of new alloy steels and steels for special purposes.

(2) To serve as a research tool for investigations into the manipulation of steel by rolling, e.g., roll pass design.

(3) To serve as a test rig for mill auxiliaries or, where applicable, particular problems arising in production mills.



In this view of the 11-in. 3-high experimental hot-rolling mill, the gas-fired muffle furnace can be seen immediately behind the mill.

These three high frequency furnaces can produce ingots (from left to right) of 5 lb., 25 lb., and 112 lb. weight respectively. The cabinet behind the furnaces contains a bank of capacitors and other electrical gear.

Rolling Range

At present, rolls are available for reducing $2\frac{7}{8}$ in. square ingots to $\frac{3}{4}$ in. or $1\frac{1}{8}$ in. diameter rounds and various intermediate squares. A further set of rolls will be available shortly for rolling $4\frac{5}{8}$ in. sq. ingots to $2\frac{7}{8}$ in. sq. billets, or various flats in thicknesses down to $\frac{1}{2}$ in. The mill is equipped for the measurement of roll separating force, spindle torque, and rolling temperatures.

The unorthodox practice of rolling a cast ingot to finished round in various qualities of steel with one set of rolls does not permit the rolling of precision products. It has been found possible, however, to produce a good quality bar which is quite satisfactory for machining into test specimens.

1956 Physical Society Exhibition

THE Physical Society Exhibition in 1956 will be held in both the Old and New Halls of the Royal Horticultural Society, Westminster, London, S.W.1., from 14th to 17th May, inclusive.

Change of Name

MACGAGGART AND EVANS, LTD., Sondes Place Research Institute, Dorking, Surrey, announce that as from 6th July, 1955, their registered name is changed to Sondes Place Research Laboratories, Ltd. Their address and telephone number (Dorking 3265/6) remain unaltered.